POTATO RESEARCH AND DEVELOPMENT IN THE REPUBLIC OF KOREA:

ORGANIZATION, IMPACT and ISSUES

INTERNATIONAL POTATO CENTER (CIP)

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Rural Development Administration

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Abbreviations

AES	Alpine Experiment Station
CIP	International Potato Center
HES	Horticultural Experiment Station
ILO	International Labour Organization
KHCA	Kangneung Horticultural Cooperative Association
M	Million
MAF	Ministry of Agriculture, Forestry and Fisheries,
NACF	National Agricultural Cooperative Federation
NAPIO	National Agricultural Products Inspection Office
OSPD	Office of Seed Production and Distribution
PSF	Kangweon Provincial Seed Farm
RDA	Rural Development Administration
R&D	Research and development
SPPA	Seed Potato Producers Association
USDA	United States Department of Agriculture
₩	Korean won (average exchange rate 1985: ₩ 870 = US$ 1.00)

Foreword

Agricultural research and development programs in developing countries and the donor agencies that support them generally allocate more resources to seed programs than to any other aspect of potato improvement. The results have been mixed. Most efforts to establish conventional seed potato certification programs have encountered serious obstacles, both technical and institutional. Few seed certification programs have been able to produce more than a small portion of the seed that farmers need to plant each year. After an initial period of growth, often based on foreign funding and technical assistance, many seed programs have collapsed when foreign support was withdrawn.

The Republic of Korea's early attempts at seed certification were no exception to this general rule. However, through persistence, discipline, and application of advanced techniques for in vitro multiplication and virus testing of potatoes, Korea's Seed Potato Certification Program has become a remarkable success.

This report summarizes the main features of the Korean experience; it outlines the seed program's technical and institutional arrangements; it indicates the magnitude of the program's costs and benefits; and it identifies some important issues that still face the program's managers. A central conclusion is that the seed program's impact, stemming primarily from technical innovation, could now be extended by turning greater responsibility for seed production over to the private sector and by expanding efforts in the areas of breeding, post-harvest technology, and on-farm research.

The report's findings should be of interest not only to potato specialists but also to a much broader audience of agricultural researchers and policymakers who are searching for ways to expand food production and improve human welfare through more effective national programs.

CIP has supported the Korean program in many ways including training, the posting of experts in the country, technical assistance, and a continuing dialogue with Korean scientists and policy makers. Nevertheless, the success of the Korean Program results primarily from the Korean government's commitment to agricultural research and development.

Richard L. Sawyer

Director General
International Potato Center
Lima, Peru

Preface

At the request of the Rural Development Administration, Ministry of Agriculture, Republic of Korea, a study of Korea's Seed Potato Program was carried out in June 1986. The main initial objective was to assess the program's economic costs and benefits. As the study progressed, it became apparent that to understand the program's benefits it was essential to look more broadly at the potato's role in Korea's food system and how the availability of quality seed influenced farmers' production decisions, potato prices and consumption. It also became clear that seed produced by the "official" Seed Program was being multiplied by an "informal" seed system about which relatively little was known.

The initial study was conducted and a report was drafted in a period of just over one month. Most interviews were carried out in the alpine seed producing area and in public offices in Suweon and Seoul. It was not possible to visit major lowland potato producing areas to discuss seed problems with farmers, traders and public officials in these areas.

In early 1987 the report, Korea's Seed Potato Program: Organization, Impact and Issues was presented to, and discussed with, officials of the Korean government. In May and June, 1987 additional statistics were gathered, interviews were conducted and a brief field visit was made to southern provinces where farmers purchase seed from the alpine area. The present report is a revised, updated and expanded version of the earlier publication, which incorporates the new information and comments obtained in 1987.

The authors are indebted to many people who took the time to meet with us, and who provided information and insights that are presented in this report. The authors would specifically like to acknowledge the valuable information provided by: J. K. Kim (Head, Horticulture Department) and Y. I. Hahm (Junior Agricultural Research, pathology) of the Alpine Experiment Station; M. C. Chung (Director) and D. H. Chung (Senior Agricultural Researcher) of the Kangweon Provincial Registered Seed Farm; I. S. Kim (Director) and J. A. Lim (Senior Officer) of the Office of Seed Production and Distribution, Daekwalryung Branch; J. Y. Kim, President of the Kangneung Horticultural Cooperative Association; W. B. Jeon, Seed Specialist of the National Agricultural Products Inspection Office; C. K. Chung, progressive potato farmer in the alpine area; O. H. Ryu, Senior Agricultural Officer(agronomist) of the Horticultural Experiment Station; I. S. Lee, Chief, Production Department of the Office of Seed Production and Distribution.

The authors would also like to acknowledge the assistance of Ms. Ok Sun Lee of the Horticultural Experiment Station for gathering statistics, and of Norma Pulcan (CIP) for processing the voluminous statistical data and preparing tables and figures. Mariella Altet and Lilia Salinas (CIP) were responsible for word processing. Valuable comments on a draft of the report were provided by J. Bryan, C. Crissman, A. Monares, and G. Scott.

Summary

Potatoes have been grown on the Korean peninsula since at least the early 1800s. Formerly, most potatoes were cultivated during summer in mountainous (alpine) areas, but over time an increasing proportion of the crop has been grown in the lowlands. At present, only about one-third of Korea's potatoes are cultivated in alpine areas and two-thirds are in the lowlands. About half the crop is produced in the spring before vegetables and other "upland" (non-irrigated) crops; an additional 10 percent of the crop is grown in spring on paddy land before rice. About 5 percent is planted in the fall after spring vegetables or tobacco and 3 percent is grown in winter on Cheju island, off the southern coast of the peninsula. Most potatoes are harvested in the summer in lowland areas where high temperatures and rainfall make storage difficult. Many farmers in alpine areas store potatoes for sale later when prices are high. Lowland farmers would like to expand the fall and winter crops to take advantage of high prices during winter and spring. However, hot, rainy summer weather, early frosts and cold winter temperatures severely limit expansion of potato production in the fall and winter.

Korea's economy was predominantly agricultural and subsistence-oriented until quite recently. Potatoes were grown as a staple food in the highlands and as a seasonal, garden vegetable throughout the lowlands. Korea's rapid economic growth, integration of the national economy and urbanization have all tended to reduce subsistence potato production, both in the highlands and the lowlands. Increasingly, potatoes are grown as a cash crop that supplies large towns and cities. Consumers' perceptions of the potato as a food are mixed. Many older people who had to survive on potatoes and sweet potatoes during World War II are averse to eating them. However, most young people like potatoes, especially when they are served in "Western" fast food restaurants.

Trends in potato consumption have been strongly influenced by the supply and price of potatoes. Because of high marketing costs, the shift from subsistence- to market-oriented production has increased the price of potatoes to consumers. During the late 1960s and 1970s, the cost of producing a hectare of potatoes rose because potato growers had to pay increasingly higher wage rates and they used more chemical fertilizers and pesticides. Due to the poor quality of seed, average potato yields remained low -- around 11 t/ha. Consequently, the cost of producing a kilogram of potatoes rose.

In the late 1970s potato yields dropped about 40 percent and total production fell by more than half. This sharp reduction in yields and production resulted from a collapse of Korea's Seed Potato Certification Program. Established in 1961, this program was based on a rather simple and loosely organized technical scheme which did not effectively control the spread of diseases. Gradually, the Seed Program's Foundation Seed stocks --the source of farmers' planting material-- became heavily infected with yield-reducing virus diseases.

In response to the virus problem and farmers' demands for better quality seed, the Korean Government reorganized the Seed Potato Program, establishing a Basic Seed Production scheme that used tissue-culture for

producing, storing and rapidly multiplying virus-free planting material. Techniques for field multiplication, inspection and pathogen testing of Foundation, Registered and Certified Seed were also improved. Quality checks became much more systematic throughout the system.

Major impacts of the re-organized seed program include a sharp reduction of virus disease symptoms in farmers' fields and a spectacular increase in yields -- from an average of 11 t/ha in the 1970s to over 20 t/ha at present. A conservative estimate is that the seed program increased farmers' incomes by approximately ₩ 17 billion (US$ 20 million) in 1984. For every won spent, the program generated about ₩ 25 in increased farm incomes. Consumers also benefited from an expanded supply of cheaper potatoes.

Surprisingly, only about 15 percent of the seed potatoes that farmers use each year are certified; the rest comes from an "informal" seed system which runs parallel to the "official" Seed Program without support, supervision or access to inspection services. It seems likely that the total benefits of the Seed Program could be increased if it were better integrated with the farmers' informal seed system.

The public sector has played an important pioneering role in establishing the Seed Potato Certification Program. However, the managerial and technical requirements for producing and distributing a large volume of high-quality seed potatoes are now stretching the capacity of the institutions involved (particularly the Provincial Seed Farm, Office of Seed Production and Distribution (OSPD) and National Agricultural Products Inspection Office (NAPIO)). Reforms on three levels might be considered:

- Transfer responsibility for producing and marketing Foundation, Registered and Certified Seed to the private sector

- Strengthen technical capacity in the key areas of seed potato inspection and certification

- Clarify the responsibilities of institutions participating in the seed program

It is generally believed that subsidies and government management of the Seed Program are needed to keep down the cost of Certified Seed potatoes. However, an economic calculation indicates that if the Alpine Experiment Station (AES) sold Foundation Seed at ₩ 1,000/kg (nearly its cost of production), private growers could profitably sell Registered Seed for about ₩ 570/kg and Certified Seed for ₩ 360/kg — about 10 percent below the price that the OSPD now charges farmers for Certified Seed.

At present, production of Certified Seed potatoes is one of the most profitable farm entreprises in Korea. This is because members of the Kangneung Horticultural Cooperative Association (KHCA) have privileged access to Registered Seed at a price that is far below its true economic value. Strengthening the operation of market forces in the seed system, by allowing more growers to participate and by charging prices for Foundation and Registered Seed that more nearly approximate their true economic values, would reduce some seed grower's earnings, but, more importantly, it would stimulate an increase in the total supply of Certified Seed and reduce its average price to lowland farmers. An expanded supply of cheaper seed would stimulate production and help reduce the price of table potatoes. This, in turn, would lead to increased potato consumption.

While the Korean potato program has been outstandingly successful in producing high-quality seed for the country's farmers, it has done less in other important areas: breeding, post-harvest technology, and on-farm research.

Since the program's inception, only one new locally bred potato variety has been released (Kangweon no. 6) and this variety has not been successful because it is susceptible to virus diseases. At present, the seed program supplies farmers with certified seed of only three varieties: Irish Cobbler, Superior, and Dejima. Given the country's diverse agro-ecological zones, potato farmers could use many more varieties. Importation and local testing of foreign cultivars should be considered as a way to help meet the country's short-term needs while new Korean varieties are being developed.

The most significant growth area for potatoes is processing. With its large metropolitan areas, rapid economic progress and burgeoning tourism, Korea presents an attractive potential market for processed potatoes: both potato chips and frozen french fries. However, potato processing has been limited by the absence of suitable varieties with high dry matter and a short growing period. Quick identification of appropriate processing varieties will require that more attention be paid to breeding, introduction of foreign cultivars, and on-farm variety testing.

To ensure a reasonably constant year-round supply of potatoes for seed, direct consumption and processing, storage research and extension are needed to identify and diffuse better ways of keeping potatoes.

The mechanisms used to communicate farmers' needs to researchers and to transfer research results back to farmers are complex and time consuming. This two-way communication, and the overall performance of Korea's agricultural R&D system, could be improved by expanding on-farm research and testing.

It is concluded that a few changes in potato R&D could generate high returns for the Korean economy and raise the status of the potato from that of a minor vegetable to that of a major food crop in the country's food system. Top priority should be on: expanding the role of the private sector in seed production and distribution, making new varieties available to farmers, improving post-harvest technology and expanding on-farm research.

1. Potatoes in the Korean Food System

With an average per capita gross national product of more than $2,000 (Table 1), the Republic of Korea is an "upper middle-income country" (World Bank, 1986). This is a dramatic change from the situation a generation ago, when Korea was one of the world's poorest countries. Over the last three decades, Korea has registered one of the highest economic growth rates of any country in the world; national product grew at an annual average rate of about 10% from 1965 to 1973 and 7% from 1973 to 1984. The country has rapidly urbanized and industrialized. By 1984, the share of agriculture in gross domestic product had fallen to less than 15 percent and the shares of industry and services had reached 40 percent and 47 percent, respectively.

Agricultural growth has kept pace with population growth and food supplies now exceed domestic caloric requirements by a comfortable margin. Nevertheless, Korea is heavily dependent on food imports; in 1984 cereal imports amounted to over 150 kg per person. An important factor behind Korea's food imports is the relative scarcity of cropland. Of the country's ten million hectares of land, only about two million hectares are arable. Hence, with a total population of 40 million, Korea has nearly 20 inhabitants per hectare of arable land.

The Korean diet is rice-based. In 1980, roughly half the calories in the national diet came from rice. However, in the quest for economic development and self sufficiency in food, the Korean government has begun to explores the potential role of food crops like potatoes which, on a per-hectare basis, can generate more food and income than rice (Horton, 1987, Tables 5 and 6).

Table 1. Republic of Korea: Basic Statistics

GNP per capita (US$)	2,110	Population per ha arable land	
		- total population	19
Population		- rural population	7
- total (million)	40		
- rural (%)	36	Fertilizer use (kg/ha)	331
Growth rates (%)		Cereal imports	
- population	1.5	- total (000 t)	6,334
- GNP per capita	6.6	- per capita (000 t)	158
- agriculture	1.7		
		Daily per capita calorie supply	
Land area (million ha)		- total	2,765
- total	9.8	- % requirement	118
- arable	2.1	- % from rice	49

Source: World Bank, World Development Report 1986 (New York, 1986); FAO, Production Yearbook 1986 (Rome, 1987); FAO, Food balance sheets 1979-1981 average (Rome, 1984). **Note:** Estimates of GNP per capita, population and cereal imports are for 1984; fertilizer use and daily calorie supplies are estimates for 1983. The estimated average growth rate of GNP per capita is for the period 1965-84; growth rates of population and agricultural production are for 1973-1984.

Introduction and Spread of Potatoes[1]

After its introduction to the Korean peninsula, reportedly in 1824, the potato was cultivated first in northern mountainous areas that had a relatively long, cool summer growing season. Gradually, potato cultivation spread from north to south and from higher to lower areas. In addition to the varieties originally introduced from Japan and China, others were brought from Europe and the Americas in the nineteenth century. In the 1920s, a series of new lines was selected from local varieties. However, only one of these, known as Nangok No. 1, became widely grown.

The old Korean cultivars are generally late-maturing and fairly tolerant to late blight and virus diseases. The plant type, with tall, rather weak vines and small leaves, resembles that of _Solanum tuberosum_ subspecies _andigenum_, the commonly cultivated potato of the South American highlands. During the last 50 years, varieties with large leaves and more compact foliage, typical of _Solanum tuberosum_ subspecies _tuberosum_, were introduced and spread throughout the Korean peninsula. The older Korean cultivars are now found only in a few isolated locations and in collections of Korean cultivars on experiment stations.

In the 1930s, the American variety Irish Cobbler was introduced from Hokkaido, Japan. In addition to its excellent culinary quality, it was earlier maturing than the older Korean cultivars, allowing farmers in many lowland areas to harvest a potato crop in the spring before rice or other crops needed to be planted. Farmers were encouraged by government organizations to produce Irish Cobbler, and it quickly become the leading potato variety in the Republic of Korea. One disadvantage of the Irish Cobbler variety was its susceptibility to virus diseases, which made it necessary to have a regular supply of healthy seed.

Since 1970, many foreign varieties have been introduced and a breeding program has been established. Two Japanese cultivars, Shimabara and Dejima, are now grown in the fall after vegetables and other upland crops. The American cultivar, Superior, is gaining popularity in the spring crop. A major advantage of Superior over Irish Cobbler is its greater field resistance to viruses. Recent interest in establishing "fast-food" restaurants has led to an intensive search for varieties that are suitable for making french fries (oblong shape and high dry matter) and which yield well under Korean conditions. To date, no specialized processing varieties have been released and Irish Cobbler, Superior, and Dejima remain Korea's principal potato varieties.

Production Zones and Systems

From the cool, northern hilly areas, the potato spread southward and to lower elevations, becoming one of the most common garden vegetables. Potatoes are grown throughout the country by as many as 90% of the farm families, in small garden plots, measuring less than one-tenth of a hectare (MAF, 1980).

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1 This and the following two sections draw heavily on Frankowiak (1978) and Anonymous (1982).

Potatoes are encountered in five distinct cropping systems in the Republic of Korea (Table 2):

- Spring crop in rainfed, upland areas
- Spring crop in irrigated paddy fields
- Summer crop in highland (alpine) areas
- Fall upland crop
- Winter crop in Cheju island

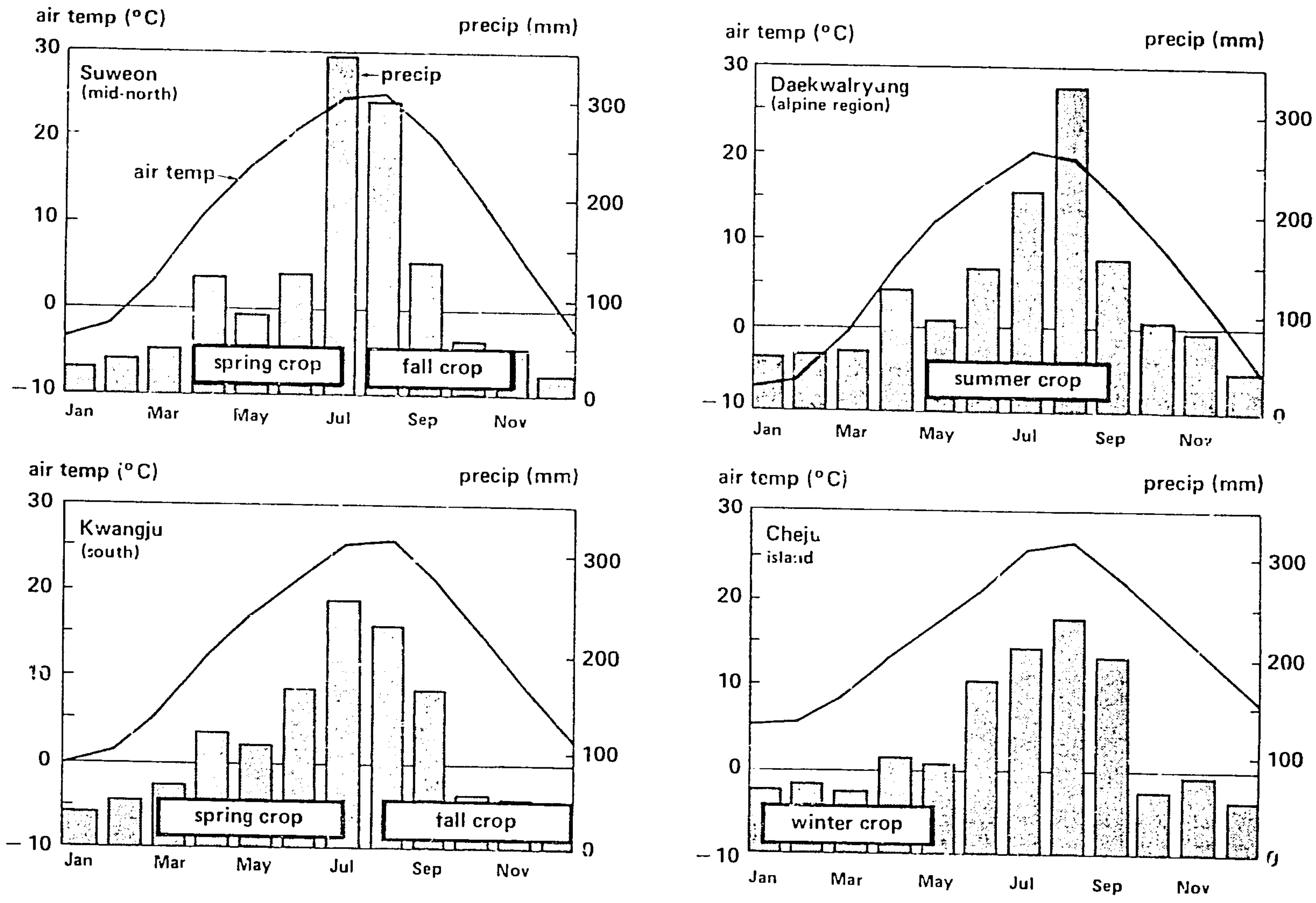
Table 2. Characteristics of main potato cropping systems

	Area (000 ha)	Yield (t/ha)	Cropping sequence	Growing season months	Growing season days	Principal location
Spring crop						
- Upland	18	16	Before vegetables	Apr-July	90-110	Hillsides throughout country
- Paddy	4	15	Before rice	Mar-June	70-90	Sandy river valleys
Summer crop	6	29	Full season	May-Sept	120-140	Northeastern highlands
Fall crop	2	13	After vegetables or tobacco	Aug-Nov	80-100	Southern hillsides
Winter crop	1	16	After vegetables or rice	Dec-April	110-130	Cheju

Source: Based on Anonymous (1982) and Kim et al (1986). See also Table A 1.2. **Note:** This table and all following tables present data for the Republic of Korea.

Over half of Korea's potatoes are cultivated in springtime in small upland fields and gardens, some of which can be observed in and around small towns and villages. This pattern was much more common in the past, when the Korean food system was more highly dependent on household production. Spring potatoes are generally planted in March or April and harvested in late June and July (Figure 1). Planting and harvest dates are earlier in southern parts of the peninsula than in the north. In small fields and gardens, potatoes are often intercropped with beans, corn, and a variety of summer vegetables. In larger fields, potatoes are more commonly grown as a sole crop. After the potato harvest, cool-season vegetables like Chinese cabbage and Korean radish are generally planted.

Figure 1. Metereological data and potato calendar



Source: Central Metereological Office, Republic of Korea, Climatic Tables of Korea
Note: Air temperature and precipitation are monthly averages for the period 1951-80

Between 10 percent and 15 percent of the potato crop is planted in February and March in paddy fields, generally on river bottom land with sandy soils and good drainage. Farmers must harvest this crop by June in order to plant rice. Because of the risk of frost in early spring, most of the spring paddy crop is planted in the southern parts of the country. In the north, in order to take advantage of high market prices, some farmers close to urban markets plant tubers in sand beds in greenhouses during late winter and transplant rooted seedpieces to the field as early as weather permits.

About 20 percent of Korea's potato crop is grown in alpine areas in the northeast. This is a full-season crop generally planted in May and harvested in September. Sole cropping is the norm and fields are comparatively large, averaging from 0.2 ha to 1.5 ha.

The fall and winter crops are small but strategic components of the Korean potato economy, supplying fresh potatoes to urban markets in winter and spring when market prices are at their highest levels. The fall crop --around 5 percent of the total-- is mostly grown in upland fields in the south. Planting is in August after spring vegetables or maize; harvesting is in November and December. Being a commercial enterprise, the fall potatoes are generally planted in relatively large fields as a sole crop. The winter crop, planted in January and harvested in April and May, accounts for less than 3 percent of the total. It is restricted to Cheju island, off the southern tip of the Korean peninsula, where benign climate permits potato cultivation throughout the winter.

Potato yields are highest in the alpine area for several reasons. Seed quality is generally better than in lowland areas because storage conditions are better and the incidence of virus diseases is lower. Alpine farmers also benefit from a longer growing seasons with more favorable (cooler, moist) growing conditions. Spring crop yields are constrained by the short available growing season. Fall crop yields are low because it is hot and rainy at planting time, and if planting is delayed frost can destroy the crop before harvest.

In the near future, significant expansion of the fall and winter crops seems unlikely. The fall crop is limited by high temperature and rainfall at planting time. The winter crop is limited by high production and marketing costs.

Potatoes in the Diet

Until quite recently, Korea's economy was largely subsistence-oriented and most potatoes were consumed by the households that produced them. In the northeastern highlands, maize and potatoes were major staple food crops. Cold winter weather after the harvest allowed households to store their own potatoes for consumption nearly year round. In the rest of the country, rice was the major staple food and potatoes were consumed as a side dish. In lowland areas, rainy summer weather and high temperatures made it difficult to store spring-crop potatoes for later consumption. Consequently, the potato played the role of a seasonal vegetable.

During the last generation, Korea's rapid urbanization and economic growth have broken the traditional link between food production and consumption. Rising incomes and improved transportation and marketing have allowed households in both rural and urban areas to diversify their diets. In alpine areas, rice has become more available and maize and potato consumption has fallen. In lowland towns and cities, potato production in household gardens has declined and shipments of potatoes from specialized commercial producing areas have increased.

During the Japanese occupation of Korea and the Second World War, rice became scarce and many people found it necessary to eat potatoes and sweet potatoes in order to survive. This experience created a stigma against root crops among survivors of the war. For this reason, consumer surveys indicate that young people have a more positive attitude toward potato consumption than their parents (Chu, Lee and Hahn, 1982).

In homes and restaurants potatoes may be either boiled or fried and served hot or cold. They are often served in soups or mixed with vegetables or seafood. French fries and baked potatoes are served in the country's western-style restaurants. In anticipation of the 1988 Olympic Games in Seoul, a number of fast food chains are opening restaurants in Korea and demand for their meals is strong. A major problem encountered by these food chains is that local potatoes are expensive and not well suited for making frozen french fries.

Trends in Production and Consumption

Potatoes are grown in all of Korea's rural districts (Figure 2). Major concentrations are in Kangweon province in the northeast and Kyongbuk, and Kyoungnam in the southeast and southern part of the peninsula. In Chonnam, the area seeded to early spring potatoes has expanded rapidly in recent years (Figure 2 and Table A 1.3).

After reaching a maximum level in 1966, Korea's potato production oscillated from 450,000 t to 650,000 t for the next decade and then declined precipitously to 304,000 t in 1978 —the lowest level in 25 years (Figure 3). Per capita potato consumption, which was 16 kg in 1965, fell to just over 5 kg in 1979 (Chu, Lee and Hahn, 1982).

The drop in potato production and consumption in the 1970s is usually explained in terms of rising incomes and declining demand for root crops (Chu, Lee and Hahn, 1982). According to this explanation, as the Korean economy developed and average income levels increased, people shifted their eating habits away from low-cost, "inferior" root crops, maize, and barley, toward the preferred staple, rice, and higher quality foods like meat, fish, fruits, and vegetables.

Figure 2. Map showing distribution of area seeded to potatoes, 1980 (each dot (•) represents 100 ha). Data provided by Republic of Korea, Ministry of Agriculture and Fisheries.

Provinces	000 ha
1. Seoul	–
2. Pusan	0.2
3. Kyonggi	2.3
4. Kangweon	10.1
5. Chungbuk	2.7
6. Chungnam	2.9
7. Chonbuk	2.8
8. Chonnam	3.3
9. Kyongbuk	6.2
10. Kyongnam	5.7
11. Cheju	1.1
Total	37.4

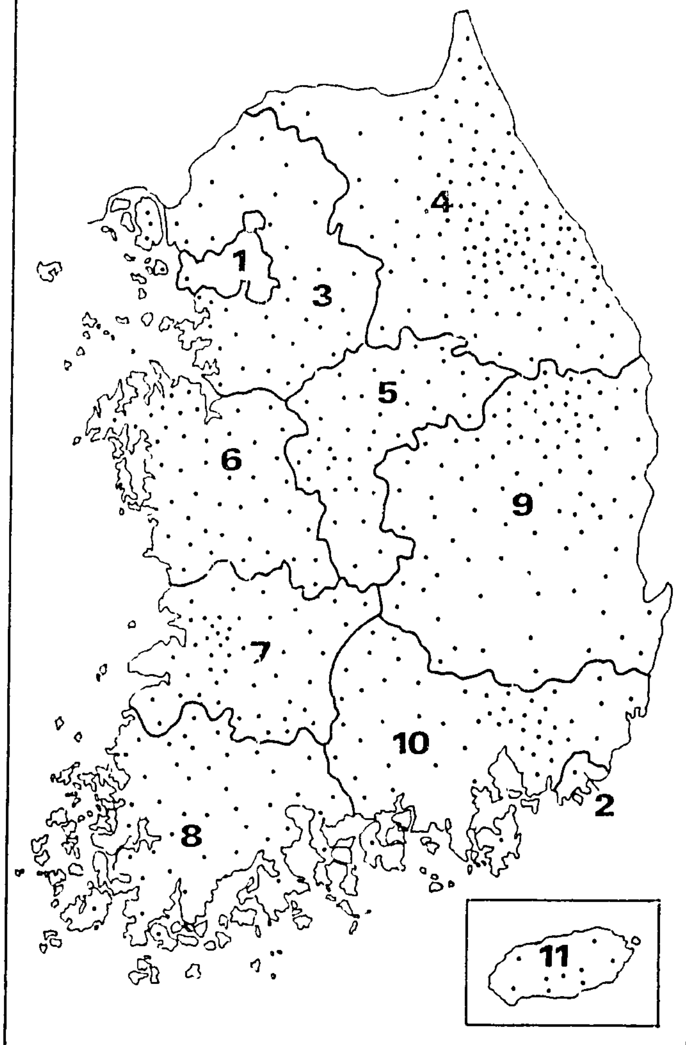
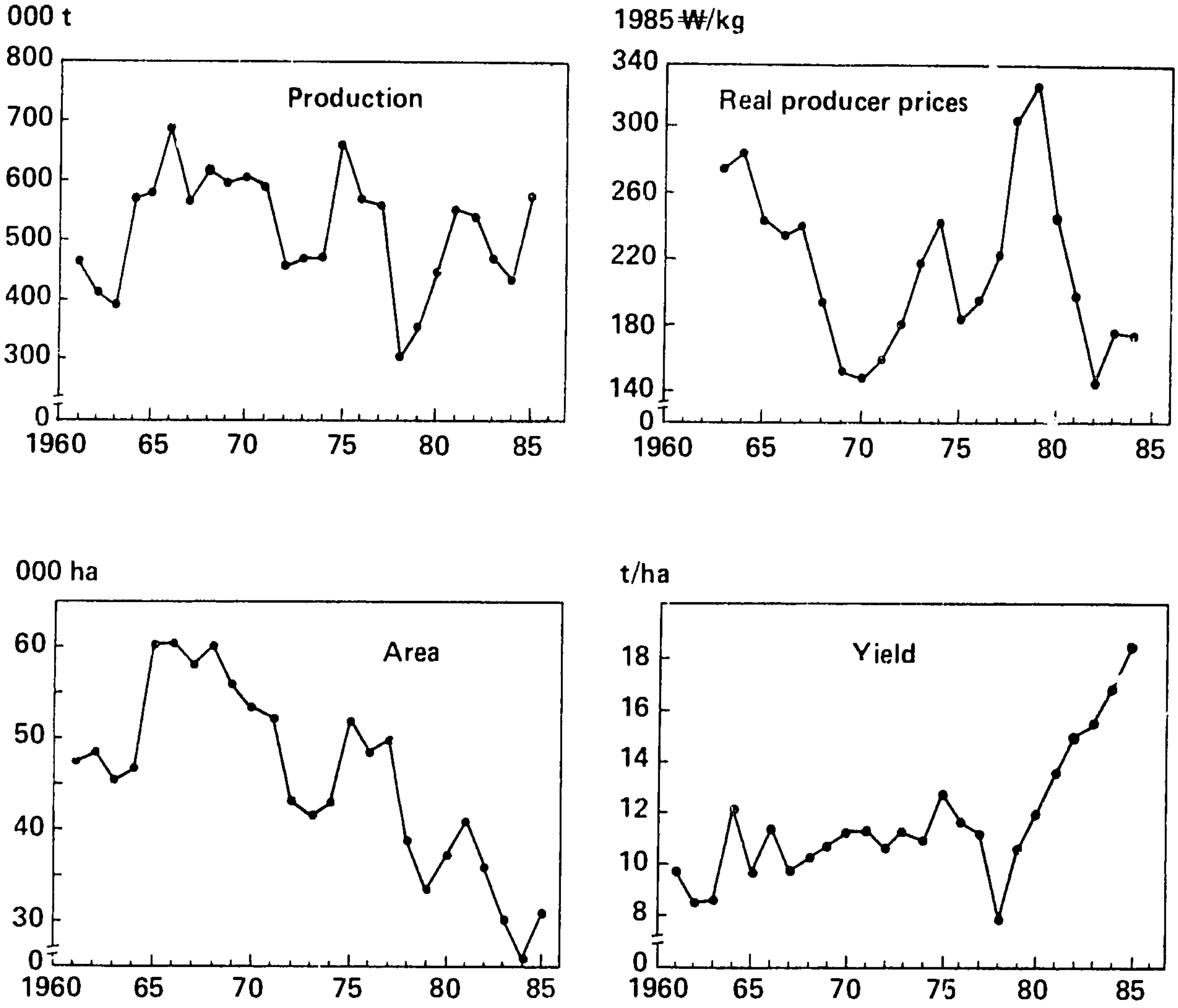


Figure 3. Potato production, area, yield, and real producer prices 1961-85



Source: Tables A 1.1 and A 4.1.

This argument ignores several important facts:

- Potatoes are relatively high in nutritional quality,
- Potatoes are relatively expensive in Korea
- Potato consumption is highest among rich people
- Urbanization has made potatoes more expensive
- Imports of potato starch have increased in recent years
- Production costs for potatoes have risen
- Potato prices rose sharply as production declined in the late 1970s
- The seed system collapsed in tha late 1970s

Many people think of the potato primarily as a source of starch. However, potatoes have relatively high-quality protein, a high protein-to-energy ratio, and they provide valuable amino acids and minerals (Woolfe, 1987).

Per unit of dietary energy and protein, potatoes are relatively expensive in Korea (Table 3). For this reason, rich people consume more potatoes than poor people do. Hence, economic growth and rising income levels can be expected to result in higher, rather than lower, levels of potato consumption (Horton, 1987, chapter 4).

Table 3. Cost of food nutrients from various foods 1984

	Price per kg. (₩)	Edible portion (%)	Food composition energy (Kcal/kg)	Food composition protein (g/kg)	Price per unit energy (₩/1000Kcal)	Price per unit protein (₩/g)
Rice a/	809	100	3,630	67	223	12
Bread b/	768	100	2,750	90	279	8
Potato	453	81	760	21	736	26

Source: Anonymous. Results of the ILO 1984 October Inquiry. ILO Bulletin of Labour Statistics. 1985-2 and USDA. Composition of Foods (Washington,D.C., 1975). a/ White, polished unenriched. b/ White, unenriched.

Since 1960, the Republic of Korea has evolved from an essentially rural country to one in which about three-quarters of the population resides in urban areas. The massive shift of population from rural to urban areas brought about a reduction in the number of potatoes produced for home consumption in rural and village gardens, and it has increased marketing costs. The marketing margin for potatoes -- about 50 percent -- represents a higher share of the consumer price than it does for most other Korean foods (Chu, Lee and Hahn, 1982).

From 1983 to 1986 imports of potato starch from Holland increased from 5,000 t to over 7,000 t. This starch, used mostly to manufacture noodles, represents the equivalent of about 100,000 t of fresh potatoes. This large-scale importation has certainly dampened the market for locally produced potatoes.

Finally, and of most direct relevance to agricultural research and extension, unit production costs for potatoes increased in the 1970s. This was partly because increasing rural wages made labor-intensive crops like potatoes relatively expensive to produce. Additionally, farmers began using more purchased inputs, like chemical fertilizers and pesticides. Nevertheless, potato yields remained low because quality seed tubers were not available. In fact, seed potatoes became so heavily infected with virus diseases that yields suddenly dropped by 40 percent between 1975 and 1978 (Figure 3). As a result of increased production costs and reduced yields, potato prices skyrocketed and both production and consumption declined significantly.

For the reasons just outlined, it seems clear that the principal reason why potato production and consumption levels fell in the 1970s was not that demand contracted but that costs rose and supply contracted. Since 1980, as Korea's seed problem has been brought under control, potato production and per capita consumption have increased to previous levels and the relative price of potatoes has declined.

2. Early Attemps at Seed Potato Certification

Most potato farmers the world over grow potato crops from tubers rather than seed *per se*. The cost, physiological condition and health of seed tubers influence potato production systems in many ways.

Seed tubers are usually the most costly single input in potato production. Data on Korea's main foodcrops show that the potato has one of the highest seed costs, and, as a result, one of the highest total production costs per hectare (Table 4). The high production cost introduces a risk factor which discourages many growers from specializing in potato cultivation.

Table 4. Production cost and seed cost per hectare for major crops 1985 (000 ₩)

	Prodn cost	Seed cost	Prodn cost less seed cost	Seed cost as % of prodn cost
Rice	1,139	34	1,105	3
Naked barley	556	51	505	9
Maize	851	37	814	4
Soybean	547	50	497	9
Potato:				
- spring	1,638	623	1,015	38
- fall	1,535	657	878	43
Sweet potato	904	169	735	19
Raddish, fall	1,040	183	857	18
Chinese cabbage,fall	1,225	106	1,119	9
Garlic	6,065	4,540	1,525	75
Hot pepper	2,103	315	1,788	15
Tomato	2,638	403	2,235	15

Source: RDA. 1986. Major indicators of Korean agriculture. Farm Managment Division Series No. 41 (Suweon), and RDA. 1986. Standard income analysis for agricultural products 1985. Suweon.

After harvest, tubers pass through a series of physiological stages that influence the development and yield of the subsequent crop. These are generally referred to as dormancy, single-sprout development (or apical dominance), multiple sprout development, and senility. To achieve high yields, farmers should generally plant seed tubers in the multiple sprout stage. Because of the relatively long dormancy period of Irish Cobbler, farmers in southern parts of the Korean peninsula cannot use tubers harvested from the spring crop as planting material in the fall. If planted, this seed would produced an uneven, late-emerging, late-maturing, low-yielding crop. For this reason, farmers plant Dejima and Shimabara, which have shorter dormancy periods.

A third major drawback of vegetative reproduction is that many yield-reducing diseases and pests -- most importantly viruses, but also bacteria, fungi, and nematodes -- can be spread by seed tubers.

Various types of seed systems have been devised by farmers and government agencies to minimize the spread of pests and diseases through seed tubers and to provide growers with reasonably priced seed in good physiological condition for planting. Most prevalent are "informal seed systems" developed over time by farmers and private merchants. Since seed tubers produced in cool areas are generally better than those from warm areas, farmers in low areas where diseases are prevalent and seed storage is difficult often buy seed tubers from mountainous areas. Farmers in northern hemisphere temperate areas generally buy seed tubers from farmers farther north. In temperate areas in the southern hemisphere, seed generally flows from south to north.

Most developed countries have established "official" Seed Potato Certification Programs to provide farmers with a trustworthy supply of planting material. Many developing countries, including the Republic of Korea, have attempted to establish similar programs, with varying degrees of success.

Due to complexity of the Republic of Korea's potato production systems, with different planting dates and growing periods in different parts of the country and production ranging from garden plots for home consumption to commercially-oriented farms, the country's seed potato systems are also complex.

Korea's Traditional Seed System

Before the Korean War, farmers in southern parts of the peninsula used seed potatoes that were produced in northern mountainous areas. The political separation of Democratic People's Republic of Korea and the Republic of Korea made it necessary to develop autonomous seed systems in the south. Private merchants occasionally imported seed potatoes from Japan, but this was discouraged by the government. Within the Republic of Korea, the alpine areas in Kangweon province emerged as the favored source of seed potatoes. Some seed was also produced in mountainous areas of Kyongbuk and Kyongnam provinces. Commercial farmers in the lowlands usually purchased highland seed, but many subsistence growers kept a few tubers from each harvest to plant the next crop. In the 1950s, most potato fields were severely infected with virus diseases, and black leg, a bacterial disease caused by *Erwinia* spp. was widespread in paddy areas. Yields averaged only about 7 t/ha (Frankowiak, 1978).

The Seed Certification Program

In 1961, Korea began seed certification for the basic food crops, including potatoes. The initial priority for potatoes was to ensure an adequate supply of quality planting material for the spring crop in the lowlands. The Alpine Experiment Station (AES) in the northeastern highlands, at Taekwanryong in Kangweon Province, was made responsible for producing the highest grades of seed potatoes -- Elite and Foundation Seed

-- for the spring crops. Foundation seed was then multiplied once by private seed growers before being distributed as Certified Seed in lowland areas. In 1966 AES also began producing Elite and Foundation Seed for the fall crop. In this case, Foundation Seed was delivered directly to table potato producers with no further multiplication (Tables A 2.1 and A 2.2).

There was no official Seed Certification Program for the summer (alpine) crop or the winter crop in Cheju island. Alpine farmers usually kept their own seed or bought non-certified seed from local seed growers. There was no adequate seed supply for Cheju island, however, until the government established a special Seed Program in the 1970s.

Technical scheme. The technical scheme for producing Certified Seed was relatively simple. There were no systematic laboratory tests for virus diseases. Little was known about potato viruses in Korea at the time, and practical methods for laboratory detection of important ones, like potato leaf roll virus (PLRV), were not available. On the assumption that potato viruses X and S (PVX and PVS) were of little practical importace, no organized attempt was made to detect or eliminate them. Seed inspection was based on visual detection of virus symptoms in the field. Field inspection was deficient because most inspectors had little knowledge of potato viruses. Moreover, only a small number of seed potato fields were actually inspected.

Until 1969, seed for the spring crop was multiplied twice on AES and once by private Certified Seed growers (Table A 2.1). In 1969/70, two additional multiplications were added to the system, one at AES and a second at the newly established Kangweon Provincial Seed Farm (PSF). Hence, during the 1970s, the Seed Potato Program involved five stages: production of Elite I, Elite II, and Foundation Seed on AES; production of Registered Seed on the PSF; and production of Certified Seed by private growers. All multiplications were carried out in the field until 1980, when net houses were erected for production of the Elite I generation.

From 1969 until 1978 AES also produced Elite I and Elite II Seed for the fall crop. Foundation and Registered Seed were produced at Cheju Experiment Station, and the Kimhae Horticultural Cooperative Association (Kyongnam province) produced Certified Seed.

Institutional scheme. In contrast to the Seed Program's relatively simple technical scheme, the institutional scheme was complex. Nine institutions were directly involved. Many with overlapping responsibilities:

- Alpine Experiment Station (AES) was responsible for producing Elite I, Elite II, and Foundation seed.

- Kangweon Provincial Seed Farm (PSF) was responsible for producing Registered Seed.

- Office of Seed Production and Distribution (OSPD) was responsible for supervising production and distribution of Certified Seed. Both the local Daekwalryung Branch and the national headquarters offices were involved.

- Kangneung Horticultural Cooperative Association (KHCA) organized production of Certified Seed on its members' farms.

- National Agricultural Cooperative Federation (NACF) handled distribution of the seed through its national-wide distribution system.

- Ministry of Agriculture and Fisheries (MAF) through the governmental administrative organization at the village, municipal, county, province, and national levels, channeled requests for seed to the KHCA and set production targets and prices for all grades of seed.

- National Agricultural Products Inspection Office (NAPIO) was responsible for inspecting and certifying seed.

- The Division of Plant Pathology of the Institute of Agricultural Science took part in the inspection of Elite and Foundation Seed.

- The MAF's Office of Plant Quarantine participated in inspection of Registered and Certified Seed.

Each year, lowland farmers who wished to obtain Certified Seed for the spring crop placed orders with district (myon) government offices (Figure 4). These orders were channeled up through the county (gun), and provincial offices to the national level, where they were communicated to the national headquarters of the OSPD. This information was, in turn, directed to OSPD's Daekwalryung Branch Office and the KHCA. Once the seed was produced by members of the KHCA, it was processed and stored in OSPD facilities and then distributed through NACF channels. The whole process could take over a year.

The MAF established production quotas and price levels for each grade of seed. In order to avoid seed surpluses in years with low potato prices, the MAF set quite conservative production goals for Certified Seed. As a result, in most years Certified Seed was in short supply and needed to be rationed among potential lowland buyers.

Trends in Certified Seed Production

The initial strategy was to produce Certified Seed on a large number of small fields (Figure 5). From 1965 until 1974, an average of 4,600 seed potato fields were inspected each year. Over this period, the average size of field increased gradually from 0.16 ha to 0.34 ha and the yield of Certified Seed rose from just over 3 t/ha to 7 t/ha. As a result of these trends the total production of Certified Seed potatoes rose from 2,700 t in 1965 to 9,800 t in 1973 (Table A 2.7). After 1974, the production of Certified Seed fell precipitously to a minimum of 650 tons in 1979. In essence, the Program collapsed.

Figure 4. Official and informal distribution systems for seed potatoes

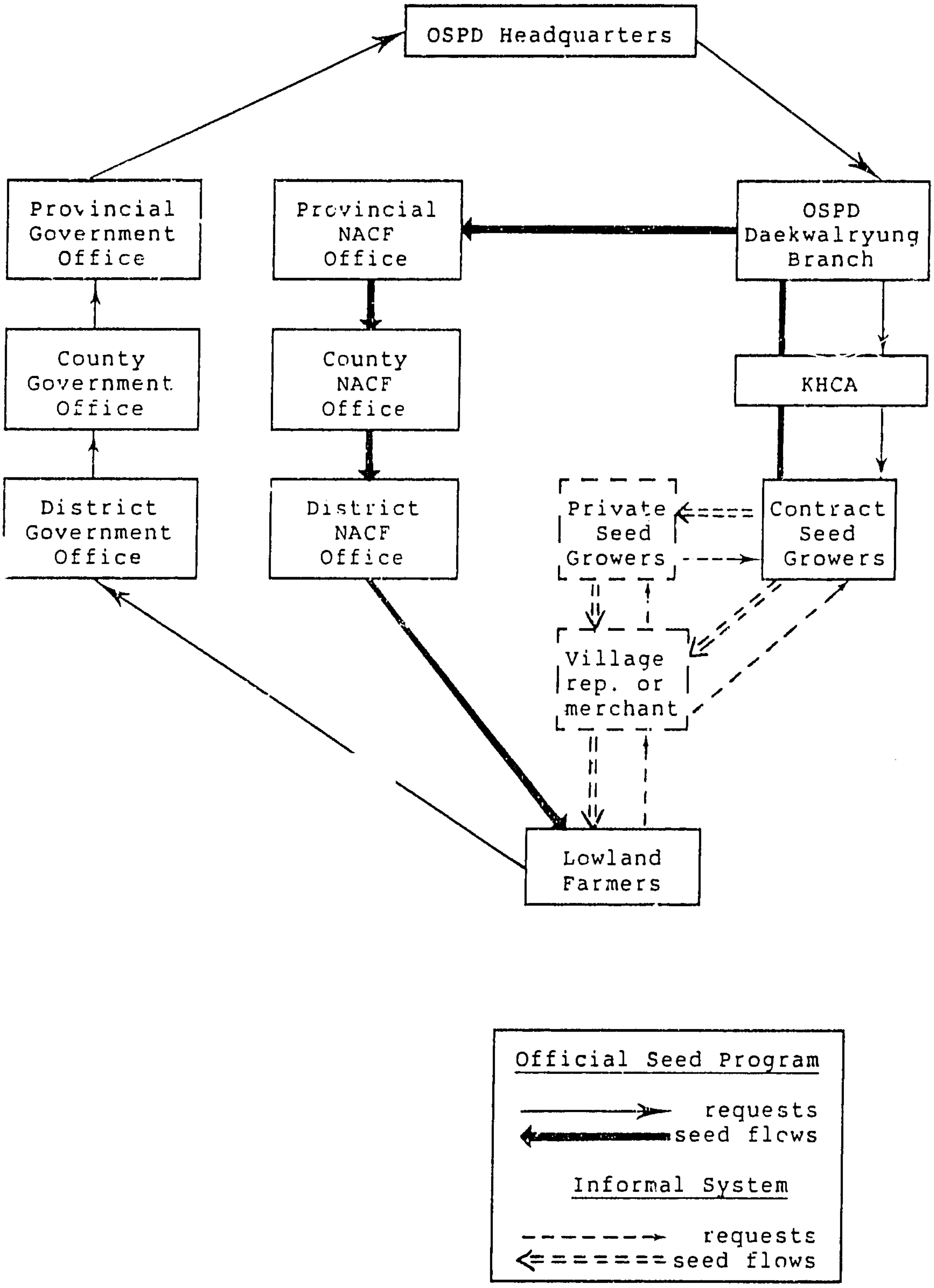
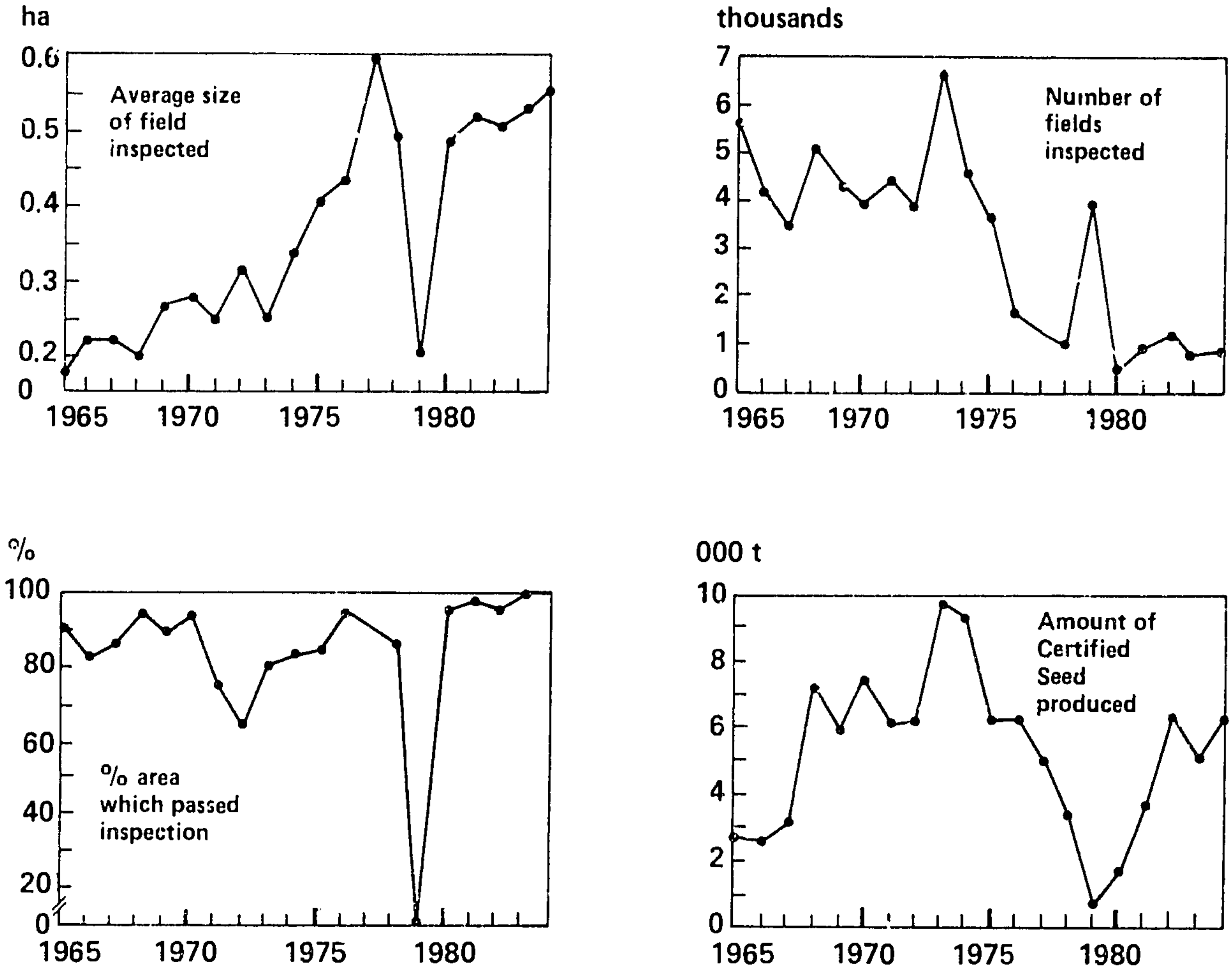


Figure 5. Trends in production of Certified Seed.



Source: Table A 2.7.

Collapse of the Program: Causes and Results

The Seed Program's collapse was brought on by a "crisis of confidence" in seed quality and a drop in farmer demand for Certified Seed. This resulted from the massive build up of virus diseases in seed stock. Yields of Irish Cobbler are strongly influenced by seed-borne virus diseases, and the Korean Seed Program's rather elemental and unsystematic approach to detection and elimination of diseased plants was not effective in controlling the spread of virus diseases. The program's collapse was precipitated by two seasons of unusually warm, dry weather in the alpine area, which led to increasing populations of virus-transmitting aphids. Alpine seed became severely infected with viruses (Annex 3). As a result, its yielding capacity declined and farmers stopped buying Certified Seed.

Seed quality became so bad that in only three years -- from 1975 to 1978 — average national yields dropped from 12.8 t/ha to 7.8 t/ha. Net returns to potato production dropped sharply and farmers reduced potato plantings. Total potato production fell by more than half, from 660,000 t to 304,000 t. Farmers complained about the poor seed quality of Certified Seed at all levels of the government up to the president's office.

In order to recover from the debacle as quickly as possible, the government authorized importation of a few hundred tons of seed from Japan in 1980, 1981 and 1982. This seed was multiplied once or twice and distributed as Certified Seed. Of far greater importance, the crisis of the late 1970s led to a reorganization and strengthening of the Seed Certification Program which put Korea's entire potato industry on a more solid technical footing.

3. The New Seed Program

Beginning in 1979, a new system was established for producing healthy seed, based on systematic virus testing and in-vitro techniques for isolating, storing, and rapidly multiplying virus-free plant materials. AES has maintained responsibility for producing seed for the spring crop. The Horticultural Experiment Station (HES) has assumed responsibility for producing Elite and Foundation Seed for the fall and winter seasons. In-vitro stages have been added to the systems both at AES and HES to produce virus-free "Basic Seed." The first three sections describe major aspects of the Seed Program established for the spring crop. The fourth section outlines some special features of the Seed Programs for the fall and winter crops.

In-vitro Stages

The new seed system uses shoot tip culture to introduce potato tissue (tubers or other plant parts) into the in-vitro, or heterotropic, state and to eliminate bacteria, fungi, and nematodes (Stage 1 in Figure 6). Multiple shoot culture is then used to quickly increase the amount of in-vitro material (Stage 2). The shoots produced are subjected to a heat treatment (39° C for 42 days) to increase the growth rate of meristems and to depress the rate of movement of viruses (particularly PVX, PVS, PVY, and PLRV) to the growing tip (Stage 3). Of 100 shoots treated, usually only five or ten survive this stage. Meristem apex culture is used to excise virus-free cells (Stage 4). Later these will be used to regenerate entire virus-free plants. Meristems that survive both the heat treatment and meristem apex culture (usually no more than one or two) proceed to Stage 5, in which multiple shoot culture is again used to quickly multiply them. From one to three in-vitro generations are multiplied in glass houses. During this period, the identity of each clone is recorded separately. If any virus is detected, the multiplied in-vitro shoots are recycled back to Stage 2 or discarded. The optional Stages 6, 7, and 8 are for in-vitro storage of virus-free tuberlets. This allows future seed production to begin at Stage 8 avoiding the preceeding shoot-tip culture, heat treatment, and meristem apex culture.

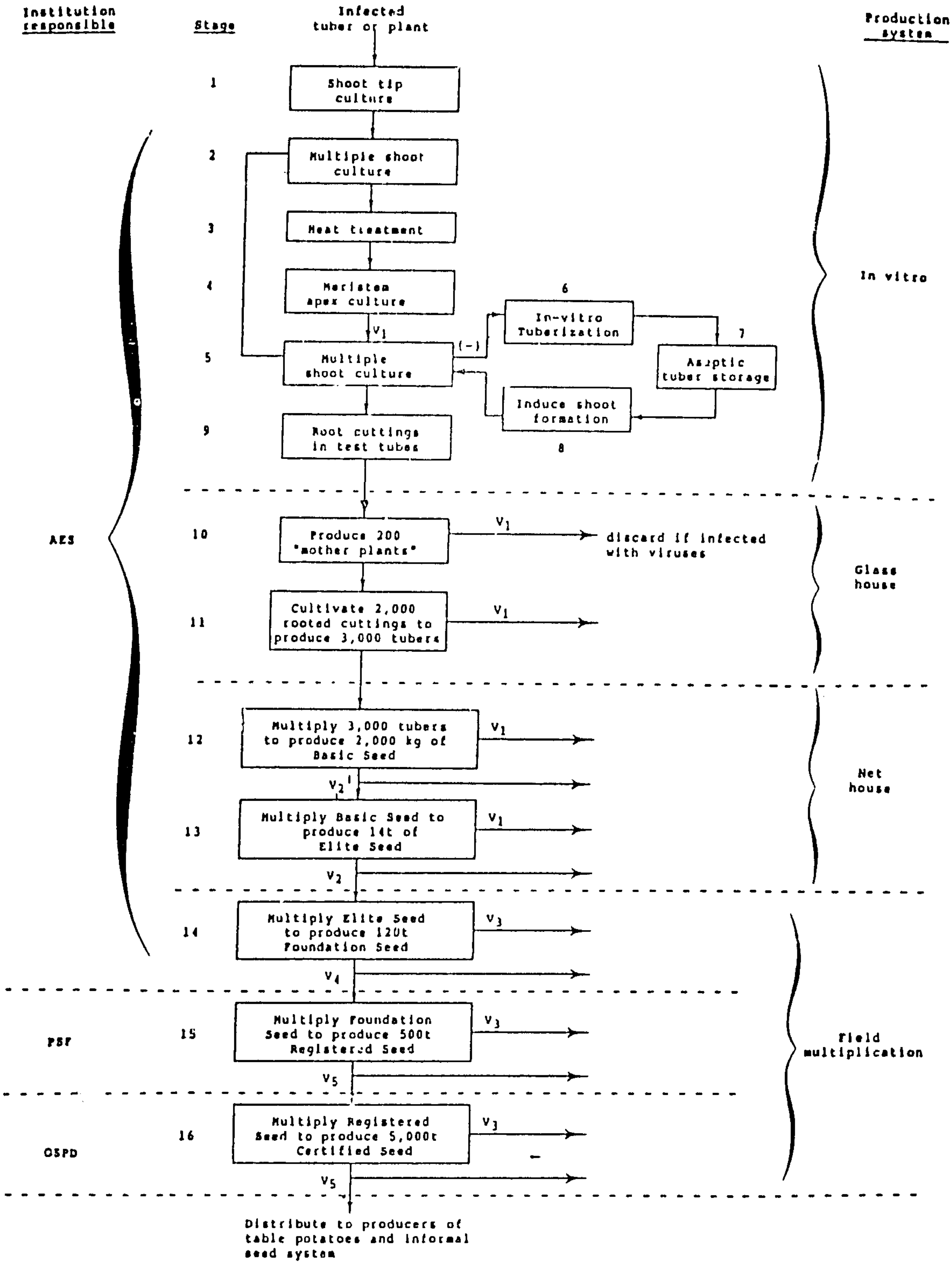
In multiple shoot culture (Stages 2 and 5), from 10 to 40 cuttings can be taken from each shoot each month. Assuming an average of 20 cuttings per shoot per month, 8,000 new plants can be produced from one shoot in three months, and over five million can be produced in five months.

In the last in-vitro stage in the system, about 200 cuttings (the number that were actually produced in 1985) are rooted in test tubes (Stage 9).

Basic, Elite and Foundation Seed

The rooted cuttings are transplanted from test tubes to pots and grown as "mother plants" in greenhouses where extreme precautions are taken to prevent the recontamination of plants with viruses (Stage 10).

Figure 6. Technical stages in Korea's Seed Potato Certification Program for spring crop



Notes

V_1 Each plant is lab-tested for viruses.
V_2 One tuber/plant is lab-tested for viruses.
V_3 Seed crops are rogued and inspected 3 times for visual symptoms of viruses.
V_4 5% of tubers are lab-tested for viruses.
V_5 Eyes from a small sample of tubers are sent to HES Suwon for "winter test" (visual).

Stages 1-14 are carried out on AES. Stages 1-9 are in-vitro. Stages 10 and 11 are carried out in glass houses. Stages 12 and 13 are in nethouses. Later stages are in the field. Stage 15 is carried out by the PSF. Stage 16 is carried out by contract growers supervised by OSPD.

Each mother plant is tested for virus diseases, and if any viruses are found, the plant is discarded. About 10 cuttings are taken from each mother plant and the resulting 2,000 plants are grown in pots in a glasshouse (Stage 11). Again, each plant is tested for viruses. About 3,000 tubers are harvested from these plants and multiplied in pots in a nethouse (Stage 12). Each plant is tested for virus diseases, as is one tuber produced by each plant. The tubers harvested at Stage 12 of the system (about 2,000 kg) is termed "Basic Seed." This seed is multiplied in nethouses to produce about 14 t of "Elite Seed" (Stage 13). Again, each plant and one tuber per plant are tested for virus diseases. The Elite Seed is multiplied in fields on the AES to produce about 120 tons of "Foundation Seed" (Stage 14). Insecticides are applied weekly to control insects that spread viruses. Foundation Seed fields are checked by a committee of seed inspectors three times during the growing season for visual symptoms of virus diseases. Before these inspections, personnel of AES walk the fields and eliminate all pants suspected of having viruses. Five percent of the tubers produced are also subjected to a "winter test" for viruses at the Horticultural Experiment Station in Suweon.

In summary, plants or tubers are routinely tested for virus diseases at nine different points in the system before Foundation Seed leaves AES. Such extreme care in controlling virus infection is needed because virus-transmitting aphids are common in Korea's alpine area and the cultivar Irish Cobbler is susceptible to virus infection.

Registered and Certified Seed

As was the case prior to 1980, Foundation Seed is multiplied by the PSF to produce Registered Seed, which is then muliplied by private growers, under the supervision of OSPD to produce certified seed. NAPIO is responsible for field inspections and the HES, Suweon, tests a sample of the harvested tubers for virus diseases during the winter season.

A number of measures have been taken to reduce the spread of viruses in Registered and Certified Seed Fields (Stages 15 and 16). The PSF has reduced the area on which it multiplies Registered Seed and has improved management. Several staff members of the PSF, OSPD, and NAPIO have been trained in practical aspects of seed potato production and pathology. Whereas Registered and Certified Seed fields used to be inspected once each season, they are now inspected three times. Furthermore, all seed fields are now inspected, whereas previously they were sampled. About 20 percent of the plants in seed field are now observed for visual symptoms of virus diseases, compared to less than 5 percent in the past.

Seed Certification for the Fall and Winter Crops

Tissue culture research began at HES in 1975 and work on meristem tip culture began in 1978. In 1979 these techniques were put to practical use in the new Seed Certification Program in which HES was made reponsible for producing Basic, Elite, and Foundation Seed for the fall season. Basic Seed produced in nethouses by HES in Suweon from in-vitro plantlets is shipped south to HES Namhae Branch Station in Kyongnam Province (Table 5). Elite and Foundation Seed are produced in the Experiment Station's fields in Namhae. Foundation Seed is then turned over to OSPD, which produces Registered and Certified Seed under contract with private farmers in the area.

Production of Certified Seed for the winter crop began in 1983. In order to provide Cheju growers with seed in optimal physiological condition at planting time in December, OSPD sends Registered Seed to the alpine area to be multiplied in the summer season.

Dejima is the dominant variety grown in the fall and winter seasons, because its short period of dormancy — about 60 days compared to 120 days for Irish Cobbler and Superior -- allows potatoes harvested in spring to be planted in the fall (and vice versa) and potatoes harvested in summer in the alpine area to be planted in Cheju for the winter crop.

Table 5. Characteristics of the Seed Program for the fall and winter crops

Seed grade	Institution responsible	Production site	Production period	Quantity 1986
Basic	HES	Suweon	All year	480 kg
Elite	HES	Namhae	Fall	5 t
Foundation	HES	Namhae	Spring	36 t
Registered	OSPD	Namhae/Muan	Fall	260 t
Certified				
- Fall crop	OSPD	Milyang	Spring	250 t
- Winter crop	OSPD	Alpine area	Summer	800 t

Source: Compiled on the basis of interviews.

4. Official and Informal Systems

Seed production figures reported by different agencies do not coincide exactly (Annex 2), but certain trends are clear . After the problems of the late 1970s, AES quickly increased production of Foundation Seed to about 175 t in 1982 and then began to gradually reduce production. The PSF increased production of Registered Seed to about 1,100 t and then also began to reduce production. Private growers in the alpine areas increased production of Certified Seed to about 5,000 t per year and maintained it at that level. NAPIO reports that in 1985, about 6,000 t of seed potatoes were certified nationally, of which, 5,000 t were for the spring and summer crops, 250 t were for the fall crop and 650 t were for the winter crop.

Use of Certified Seed in the spring and fall crops has fluctuated from year to year, largely in response to price movements for table potatoes. In contrast, use of Certified Seed in the winter crops has increased each year since production began in 1983.

The Official Seed Certification Program

In 1985, Korean farmers planted about 31,000 ha of potatoes, using 38,000 t of seed tubers (Table 6). Most of the seed for the spring and fall crops and around half of that for the alpine crop is purchased. Hence, approximately 27,000 t of seed tubers were purchased in 1985. In 1984, about 6,000 t of Certified Seed were produced (Table A 2.7), representing 16 percent of the total seed requirement and 22 percent of the amount of seed that farmers bought in 1985. In other words, the Republic of Korea's official Seed Program supplies less than one-fifth of the seed potatoes planted. The remainder is supplied by a much larger "informal" seed system (Figure 7).

Why is so little Certified Seed produced? One reason is that yields on seed farms are low. Fields of Foundation, Registered, and Certified Seed are reported to yield only 5 to 10 t/ha (Table A 2.1), whereas average yields in the alpine region are over 25 t/ha. The reported yields on seed farms are deceptive, however, because they do not reflect total production but only the amount of seed that was passed on to the next stage in the system. Total yields average about 20 t/ha on AES, the PSF, and Certified Seed growers' fields (Tables 11, A 2.3, A 2.4, A 2.6). The large gap between total yields and the amount of seed flowing through the formal seed system reflects substantial "leakages" or "escapes" of high-quality seed out of the system. These leakages result from the conservative production quotas and fixed prices that are set for each category of seed.

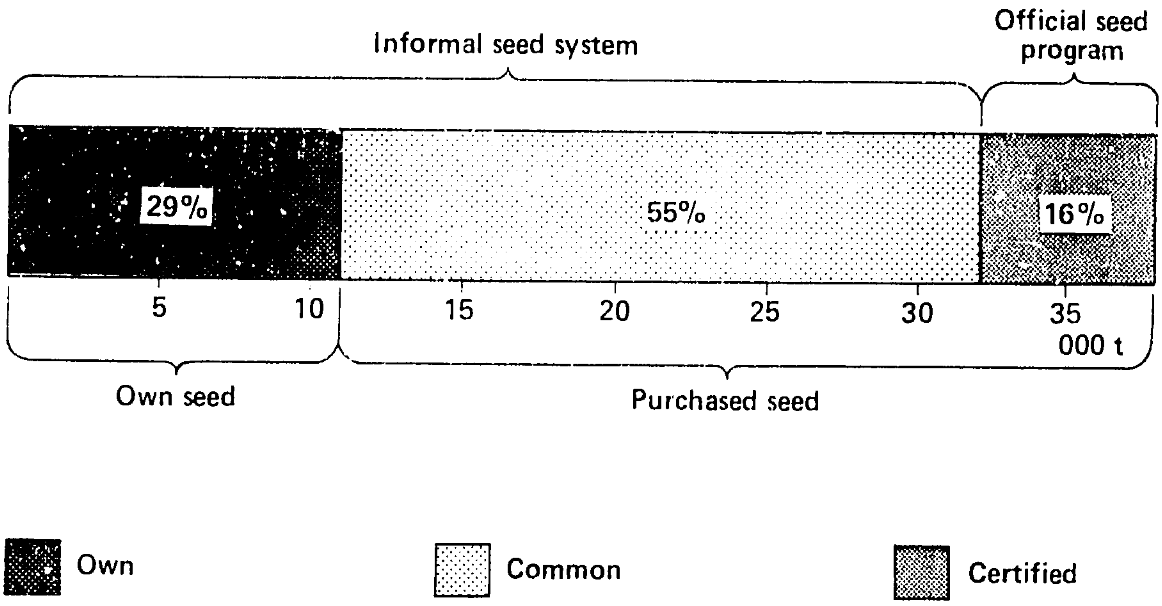
The Seed Program has built-in incentives for the AES, PSF, and KHCA to produce more seed than is needed to meet the production quotas and to sell the surplus to the private growers who operate in the informal seed system. AES is required to deliver a set amount of Foundation Seed to the PSF free of charge. The PSF, in turn, must deliver a specified quantity of Registered Seed to OSPD at ₩ 214/kg — well below the market price for common seed in the region.

Table 6. National seed potato requirements

Season	Area (000 ha)	Seed rate (t/ha)	Seed reqmt (000 t)	Purchased seed % reqmt	Purchased seed 000 ton
Spring	22	1.2	26.4	75	19.8
Summer	6	1.3	7.1 a/	50	3.5
Fall	2	1.5	3.0	75	2.2
Winter	1	1.5	1.5	75	1.1
Total	31	1.2	38.0	70	26.7

Source: Area: official estimate of the MAF; seed rate and percent seed purchased: Chu, Lee and Hahn (1982) estimates of the Farm Management Division, RDA, and personal observations. a/ Approximately 550 ha of the summer (alpine) crop are in the Seed Program (460 ha are used for producing certified seed, 80 are used for producing Registered Seed, and 10 ha are used for producing Foundation Seed). Hence, the total seed requirement for potato farms outside of the Seed Program is 7,085 t (5,450 ha x 1.3 t/ha).

Figure 7. Sources of farmers' seed potatoes.



Source: Table 5 and A 2.7.

The MAF sets low prices for Foundation and Registered Seed to subsidize seed production and ensure that an adequate amount of Certified Seed is produced. On the other hand, the MAF sets conservative production targets for each seed category to ensure that all the Certified Seed produced is sold at its pre-determined fixed price, even in years when the market price for common seed is unusually low.

The major "leakage" of quality seed is from the PSF, which has an economic incentive to maximize returns by selling as much seed as possible to private farmers who offer higher prices than OSPD pays. Because Certified Seed growers obtain Registered Seed from PSF at an artificially low price, they too are motivated to produce more potatoes than is required to meet their quota for Certified Seed and to sell the surplus as high-quality non-certified seed.

Adding to these leakages of Registered and Certified Seed, from 1979 to 1984 AES bypassed the PSF and sold substantial amounts of Foundation Seed directly to the OSPD and to the KHCA in order to accelerate the diffusion of clean seed in the alpine area.

It is for these institutional reasons, not technical ones, that Korea's Seed Program produces only a small share of the country's total seed requirement.

The Informal Seed System

Farmers in the alpine area are among the principal beneficiaries of Korea's Seed Potato Program. In 1984, they purchased about 1,200 t of Certified Seed and more than 2,000 t of Foundation-, Registered- and Certified-quality seed from AES, the PSF and private Certified Seed growers (Table 7). This large infusion of quality seed is an important reason why yields in the alpine area are well above the national average. While most alpine farmers sell their harvest as table potatoes, a select group of relatively large, experienced farmers produce seed in an "informal" seed system that operates outside of the official seed program. Each year they purchase high-quality seed potatoes which they multiply and sell to lowland farmers as non-certified seed. Since these producers obtain their seed from the AES, PSF, or members of the KHCA, the informal seed system is, in effect, an extension of the Official Seed Program.

The Official Seed Program and the informal seed system are complementary in several respects. For lowland farmers, obtaining seed from the Official Seed Program is generally less risky but more burdensome than purchasing seed from the informal system. Certified Seed is sold nationwide at a fixed price which is generally higher than the price of seed available in the informal system. Except during the 1975-80 period, Certified Seed has been of relatively high and dependable quality; seed from the informal system is of less dependable quality. Certified Seed is usually in short supply and is rationed to growers in small lots; seed can be obtained in any quantity in the informal system if the buyer is willing to pay the going price. The price of certified seed is fixed; in contrast, the price of seed in the informal system fluctuates widely depending upon supply and demand conditions. A considerable amount of planning and paperwork is needed to obtain Certified Seed; this can be avoided by dealing with the informal system. Certified Seed is delivered to villages through the nation-wide distribution system of the NACF; seed in the informal system must be obtained in the alpine area or from merchants who purchase it there. Many villages send representatives to the alpine area to purchase seed. These representatives usually become established clients of one or a few seed producers who have a good reputation for producing quality seed.

Table 7. Estimation of alpine potato farmers "official" and "informal" seed production 1984 (t)

Certified seed produced		1,200
"Leakages" from the official program		
Foundation Seed	105	
Registered Seed	743	
Certified Seed	3,460	
Sub-total	4,308	
Assume 50% used for seed		2,154
Total seed produced		3,354

Source: Tables A2.3, 2.4, 2.6 and 2.8. The estimated leakage of Certified Seed assumes that seed growers sell 10 t/ha (or roughly half their output) outside the Seed Program. This assumption is based on interviews with members of the KHCA and private seed growers in the alpine region.

In conclusion, Korea's Official Seed Certification Program and the informal system are intimately and symbiotically linked in many respects. The informal system obtains high-quality seed from the Official Seed Program. Hence, the quality of seed distributed by the informal system depends on the quality of seed produced and distributed in the alpine area by the Official Seed Program. The Official Program also provides farmers in lowland areas with a steady, dependable, but limited supply of high quality seed at a reasonable price. The informal system fills the country's residual seed requirement by multiplying seed obtained from the Official Program and selling it as seed or table potatoes depending upon prevailing market conditions.

5. Costs and Benefits

The Korean Seed Program is so complex that a detailed economic assessment is beyond the scope of this paper. However, through the use of available budgetary documents and production estimates, the program's costs and benefits can be estimated in general terms.

Costs

Five principal institutions incur costs because of their participation in the Seed Program: the AES, PSF, OSPD, NACF, and NAPIO. Budgetary documents available at AES, the PSF, and the Daekwalryung branch of OSPD indicate that from 1983 to 1985 their participation in the Seed Program resulted in expenses averaging approximately W 550 M (Table 8). It is more difficult to estimate the Seed Program-related expenses of NAPIO, NACF, and the national headquarters of OSPD, since work with potatoes represents only a small part of their activities. Based on budgetary figures and interviews with management personnel, their expenses for 1984 are estimated to be W 150 M. This results in an estimated total annual cost of W 700 M (US$ 800,000) for the Seed Program in the period 1983-85.

Table 8. Estimated budget for Seed Program 1983-85 (million W)

	1983	1984	1985
AES	214	228	231
PSF	174	109	72
OSPD local branch	208	211	213
Sub-total	(596)	(548)	(516)
OSPD headquarters	20	20	20
NAPIO	100	100	100
NACF and other costs	30	30	30
Sub-total	(150)	(150)	(150)
Total budget	746	698	666

Source: Figures for AES, PSF, and OSPD local branch are from budget documents. Estimates for OSPD headquarters and NAPIO are based primarily on interviews with management personnel of these institutions and a rather superficial look at budgetary figures. The estimate for NACF and others is based solely on interviews. Estimates include operating expenses, interest, rent, and depreciation on capital.

In addition to the costs incurred by the various institutions involved in producing and distributing Certified Seed, farmers now pay slightly more, in real terms, for Certified Seed and improved common seed than they paid for seed in the mid-1970s. According to official estimates in 1985 Korean won, seed cost on average ₩ 285/kg from 1975 to 1979, whereas in 1984 it cost ₩ 340/kg (Table A 4.1). The difference of ₩ 56/kg can be considered an additional cost of the Seed Program. Hence, the additional costs of the 24,000 t of seed used in the spring and summer crops is approximately ₩ 1.3 M (US$ 1.5 M).

Benefits

From 1970 to 1976, spring and summer potato crops yielded on average 11.4 t/ha. By 1985 yields had climbed to an all-time high of 18.5 t/ha and in 1986 yields averaged 20.4 t/ha. Farmers, researchers and extension agents concur that this yield increase is due mainly to improved seed quality. Some other factors have undoubtedly contributed to the increase. One is that subsistence production in home gardens has declined and potato production has become more concentrated on better quality land. A second factor is that more farmers are now using "plastic mulch" — planting potatoes under strips of plastic that raise soil temperature, conserve moisture and help control weeds in the spring season. Farmers are also using somewhat more fertilizer and pesticides. Information compiled by the RDA's Farm Management Division indicates that since 1979 national average real production costs per hectare, net of seed, have changed relatively little (Table 9). Hence, it seems reasonable to conclude that at least half the increase in yields is due to use of improved seed.

If we assume that yields in 1985 were 3.5 t/ha above what they would have been without the seed program the increased value of potato production, at the average farm-gate potato price of ₩ 248/kg, was ₩ 868,000/ha. Applied over the 29,000 ha of potatoes grown in the spring and summer crops, the incremental value of national potato production was roughly ₩ 25,000 M (US$ 28 M).

Table 9. Potato production costs per hectare 1979-85 (000 ₩/ha)

	Total cost	Seed cost	Total cost net of seed: current	Total cost net of seed: real
	(..........current prices	........)		(1985 prices) a/
1979	1,411	261	1,150	1,936
1980	1,823	365	1,458	2,011
1981	2,290	566	1,724	1,858
1982	2,360	512	1,848	1,861
1983	2,698	606	2,092	2,063
1985	2,855	623	2,232	2,232

Source: RDA. Farm Managment Division and Table A 4.1. a/ Deflated by index of all prices paid by farmers (1985=100).

Comparing the costs and benefits, Korea's Seed Potato Program has apparently generated net benefits of approximately ₩ 24,000 M (nearly US$28 M) in 1985 and it had a benefit/cost ratio of 24:1. In other words, for every ₩1,000 spent on the program, ₩24,000 were generated in additional farm incomes. Aside from these benefits to potato producers, consumers also benefited from expanded supplies and reduced prices. In the early 1980s, the real price of potatoes was about ₩ 65/kg less than it was in the early 1970s (Table A 4.3). Assuming that half the price reduction was due to improved seed quality and that 60 percent of the potatoes harvested were consumed, the Seed Program's total annual benefits to consumers was approximately ₩10,000 M.

6. Some Issues for the Future

The Korean Seed Potato Program is clearly successful. It produces and distributes high-quality seed, it is fully institutionalized in the country's agricultural research and development system, and it generates substantial economic benefits. This final section addresses five issues that are likely to influence the future performance of the program.

- The amount of Certified Seed to produce
- The need for government subsidies to keep seed prices low
- The need for government involvement to ensure high seed quality
- The role of the private sector in seed production and distribution
- The priority areas for future potato R&D

How Much Certified Seed Should Be Produced?

The Seed Program is currently providing less than 20 percent of the total seed requirement. Hence, one might conclude that production of Certified Seed should be greatly increased. However, OSPD is hesitant to increase production. When it did so in 1982, the result was a surplus of Certified Seed potatoes that was disposed of by distributing it to staff members of the MAF and deducting the cost from their salaries. In other words MAF employees were penalized for overproduction of seed potatoes.

Surpluses of any commodity, including seed potatoes, can only occur if the price is fixed above the market equilibrium price. The market prices of table and seed potatoes produced in the informal sector fluctuate continually in response to changing conditions of supply and demand. Hence, there is always a risk that the market equilibrium price of seed will fall below the government-mandated price resulting in a surplus of Certified Seed. From 1978 until 1981 potato production increased by more than 80 percent. The result was a drop in prices which motivated farmers to reduce the area seeded to potatoes in 1982. When OSPD increased the supply of Certified Seed that year and maintained a fixed price, the inevitable result was a surplus.

Whereas public employees are penalized for overproduction of Certified Seed, there are no similar penalties for underproduction. The logical result is that officials tend to set conservative production targets for Certified Seed. For this reason, it is unlikely that production of Certified Seed will be expanded significantly. As will be shown below, expanding the supply of Certified Seed could increase the Seed Program's economic benefits. However, achieving this would require a more flexible, market-oriented system.

Are Government Subsidies Needed to Keep Seed Prices Low?

To date, AES has delivered Foundation Seed to the PSF free of charge. The PSF delivers Registered Seed to OSPD at a price of ₩ 214/kg. OSPD, in turn, pays its contract growers ₩ 345/kg for Certified Seed. This price structure, with the top grade seed being given away free and the bottom grade selling for the highest price, contrasts sharply with the price structure that would result from the free operation of market forces (Figure 8). In a market-oriented system, input prices reflect their relative levels of productivity. Hence, in countries like Holland and the USA, the price of Foundation Seed is higher than that of Registered Seed, which in turn is higher than the price of Certified Seed.

The principal justification for the peculiar price structure in Korea is to ensure that an adequate supply of Certified Seed is made available to lowland farmers each year at reasonable prices. It is assumed that if Foundation Seed were sold at cost and Registered and Certified Seed were produced by private growers in a free-market environment, less Certified Seed would be produced and its price would be higher. This assumption is questionable. It has already been noted that the supply of Certified Seed meets only a small fraction of the total seed requirement. Data from the MAF also show that since 1981 the price of seed potatoes has been higher, relative to the price of table potatoes, than during the previous decade (Table 10). Hence, an important question is: Could a market-oriented seed system, without production targets, fixed prices, or subsidies, produce Certified Seed as abundantly and cheaply as the present system?

Table 10. Prices of seed and table potatoes 1967-86

	Table potatoes	Seed potatoes	Relative seed price a/
	(.......₩/3.75 kg......)		
1967	61	86	141
1968	58	108	186
1969	54	99	183
1970	60	142	237
1971	78	172	221
1972	108	176	163
1973	142	199	140
1974	211	313	148
1975	195	307	157
1976	260	324	125
1977	345	386	112
1978	612	569	93
1979	726	776	107
1980	667	1,006	151
1981	689	1,236	179
1982	539	1,221	227
1983	669	1,268	190
1984	656	1,277	195
1985	876	1,474	168
1986	782	1,513	193

Source: Table A 4.1. a/ (Seed price/table potato price)*100.

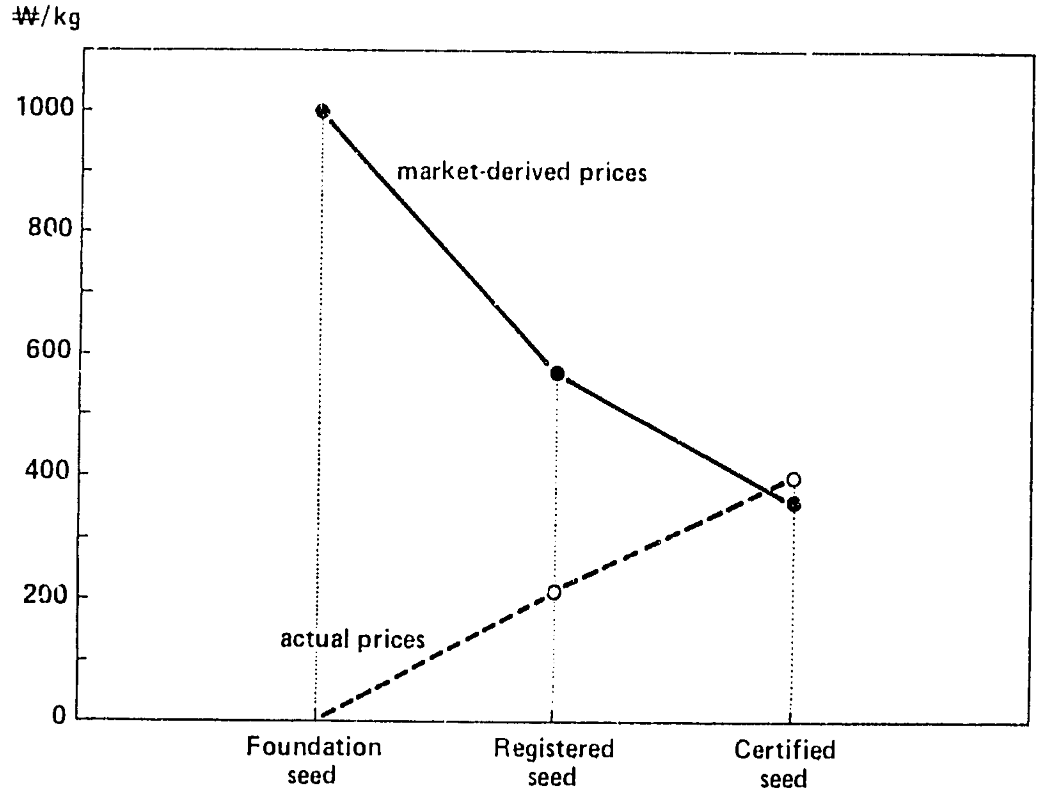
The present quota system and pricing structure, with heavily subsidized prices for Foundation and Registered Seed is highly beneficial to the PSF and to members of the KHCA, who obtain Foundation and Registered Seed at far below the true market value. It is not clear, however, that this system is beneficial to table potato producers or to consumers.

Within the official norms of the Seed Program, the PSF has exclusive access to Foundation Seed and members of the KHCA have exclusive access to Registered Seed. Accounts of the PSF, of members of the KHCA, and of commercial producers of table potatoes indicate that the PSF is a high-cost producer of Registered Seed and that members of the KHCA earn exceptionally high profits from Certified Seed production (Table 11).

The PSF's costs are particularly high in the areas of salaries and wages, capital, and administrative overhead. Since the PSF does not have technicians with specialized training in seed production, most observers believe that experienced private farmers in the area could produce high-quality Registered Seed more efficiently and cheaper than the PSF.

Because members of the KHCA have exclusive access to Registered Seed at a subsidized price and they sell Certified Seed at a higher fixed price, production of Certified Seed potatoes is one of the most profitable agricultural enterprises in the Republic of Korea, and contract seed growers are among Korea's wealthiest farmers. In 1984 and 1985 net earnings of seed growers were 60 percent over total production costs (Table 11).

Figure 8. Actual and market-derived prices of Foundation, Registered and Certified Seed



Source: Tables 10 and A 2.9.

Table 11. Estimated production costs and returns per hectare for Kangweon Provincial Seed Farm, contract seed growers and table potato producers (000 ₩)

	Provincial Seed Farm	Contract seed grower	Table potato producer
Seed	0	300	623
Fertilizer	615	611	309
Pesticide and herbicide	226	306	42
Light and fuel	299		23
Other materials	472	165	253
Depreciation		183	
machinery	201		75
buildings	78		15
Repairs	231	3	16
Taxes and charges	196	56	56
Hired labor	1,610	936	227
Family labor	1,922	396	807
Interest			
operating capital	182	121	32
fixed capital	223	910 a/	63
Rent	834		315
Total cost	7,089	3,987	2,856
Gross return		6,537 b/	3,560 c/
Percent return d/		64	25

Source: Cost estimates for the PSF are from PSF records. Estimated costs and returns for a representative seed grower are from KHCA records. Estimates for a commercial spring-crop grower are from RDA Farm Management Division (official estimates). a/ Includes rent. b/ Farmers produced 14.3 t/ha of seed potatoes valued at ₩ 345/kg and 7.9 t/ha of table potatoes valued at ₩ 200/kg. c/ Farmers produced 17.8 t/ha of table potatoes valued at ₩ 200/kg. d/ (gross return-total cost)/total cost.

It is likely that a more open system with flexible prices and opportunities for a broader range of private farmers to produce Registered and Certified Seed would produce more Certified Seed at a lower price. The following calculations illustrate this likelihood.

The 1984 production cost for Foundation Seed is estimated to be just over ₩ 1,100 (Table 12). If AES sold Foundation Seed to private farmers for ₩ 1,000/kg, these farmers could profitably grow Registered Seed at a cost of about ₩ 500/kg and sell it to Certified Seed growers for ₩ 570/kg. Certified Seed growers, in turn, could profitably sell Certified Seed to lowland producers of consumer potatoes for about ₩ 360, or 10 percent less than the price OSPD currently charges (Table A 2.9). It is important to note that the only direct production subsidy in these calculations is the difference between the production cost and selling price of Foundation Seed. A second notable point is that this type of market-oriented system would generate substantially more Certified Seed than the present Seed Program. At the yields and seed rates assumed in Table 11, the initial 200 t of Foundation Seed would generate 2,000 t of Registered Seed and, potentially 20,000 t of Certified Seed. If only half this target were obtained, Certified Seed production would still be nearly double the current level.

Table 12. Production cost estimates for Foundation, Registered and Certified Seed 1984

	000W	W/kg
Foundation Seed		
Prodn cost/kg		1,140 a/
Registered Seed		
Prodn cost/ha net of seed b/	4,424	
Plus seed cost c/	+ 1,500	
Plus 25% profit	+ 1,481	
Less sale of table potatoes d/	- 1,000	
= Cost of 15t Registered Seed	6,406	
Prodn. cost/kg		494
Plus 15% for storage and marketing		+ 74
= Price to Certified Seed growers		568
Certified Seed		
Prodn cost/ha net of seed e/	3,687	
Plus seed cost (W 586 x 1,500 kg)	852	
Plus 25% profit	+ 1,135	
Less sale of table potatoes d/	- 1,000	
= Cost of 15 t Certified Seed	4,674	
Prodn cost/kg		311
Plus 15% for storage and marketing		47
= Price to growers of table potatoes		358

Sources and Notes: a/ AES budget for Seed Program divided by Foundation Seed produced in 1984 (W 228 M/200 t) derived from Tables 7 and A 2.3. b/ The production cost for Registered Seed growers, net of seed, is assumed to be 20 percent greater than Certified Seed growers (derived from Table 10). c/ This calculation assumes a seed rate of 1,500 kg/ha and a price of W 1,000/kg for Foundation Seed. d/ Assumes that farmers sell one-third of the harvest (5t/ha) as consumer potatoes at a price of W200/kg. e/ From Table 10.

Is Government Control Needed to Ensure High Quality?

A major justification for the government's heavy involvement in seed potato production (particularly the production of Registered Seed) is that high standards of seed quality would not be maintained if responsibility were turned over to the private sector. This argument overlooks the fact that the key to Korea's success in seed potato production is in the virus-free basic seed supplied annually by AES and HES. Once this seed reaches the field, infection begins, and the virus detection and elimination procedures used in field inspections and winter tests have not been entirely satisfactory. The PSF, which is responsible for producing all the registered seed for spring and summer crops, does not have tecnically trained personnel for seed potato production. Hence, as long as AES and HES continue to produce virus-free basic seed and as long as a "flushout system" is used (with no seed re-certified) there is little reason to believe that Registered Seed produced by qualified private growers would be of lower quality than that produced by the PSF.

What is the Appropriate Role of the Private Sector?

Seed inspection is probably the weakest link in the present seed system, and it would surely be so in an expanded system that involved many more private seed growers. Rigorous field inspection is essential to ensure high quality standards and to pinpoint the responsibility for deficiencies when they arise. NAPIO has had more problems with seed potatoes than with any other crop. NAPIO does not employ specialized seed potato inspectors. Its field staff is responsible for inspecting all crops. The requirements for inspecting cereals are quite different, and much simpler, than those for potatoes. The main task for inspectors of rice and other grains is to check for the presence of weed seeds and varietal mixtures in seed lots. In potatoes, it is essential to observe plants in the field and to correctly identify symptoms of viruses as well as other diseases and pests. This requires a great deal of training and experience. Since the potato growing season is short, certification also takes good planning, coordination, and an ample transportation budget.

High quality standards are maintained in the Basic Seed through systematic laboratory testing for viruses. In the later field multiplication stages, because of the large volume of potatoes that must be inspected, virus identification is inevitably less systematic and relies mainly on visual inspection rather than laboratory tests.

Formally, NAPIO is responsible for seed inspection and certification, but in this area, as in the larger seed system, an "informal system" operates. Since NAPIO does not have an adequate number of trained seed potato inspectors, and because staff of the various institutions participating in the Seed Program feel responsible for seed quality, a type of inter-institutional team system has evolved for seed inspection. When Foundation Seed is inspected on AES, representatives of the PSF, KHCA, HES, and MAF participate along with NAPIO personnel. When Registered and Certified Seed is inspected, AES staff members also take part. In essence, seed is certified on the basis of a consensus of representatives of the participating institutions in the seed program, rather than on the basis of rigid technical criteria.

If the Seed Program were to move in the direction of a market-oriented system, with many more private farmers and significantly larger volumes of seed involved, maintenance of quality standards would necessitate a more rigorous and systematic approach to seed potato inspection, testing and certification. More clearcut responsibilities, quality standards, and criteria for acceptance or rejection of fields and seed lots would be needed. It would also be essential to strengthen of the technical capabilities of the institution responsible for seed potato inspection and certification through training and specialization of personnel in work with seed potatoes. More manpower and an expanded budget for field inspections and laboratory testing would also be required. These resources could be provided from a portion of the savings resulting from eliminating the present subsidies for producing Foundation, Registered and Certified Seed.

The successful devolution of responsibility for producing seed require that private farmers receive specialized training in practical aspects of seed potato production. They would also need to take greater responsibility for the quality of seed they produce. A specialized Seed Potato Producers Association could play useful roles in training and development of group responsibility for seed quality. Such an association could also provide a mechanism for financing seed inspection and testing.

The public sector, through the MAF and its affiliated organizations, has played a crucial, pioneering role in establishing the Seed Potato Certification Program. However, the program's future performance might be enhanced by focusing the public sector's resources more sharply on those activities for which it has a comparative advantage: research, production of Basic and Elite Seed, inspection, and certification. The private sector could gradually take over responsibility for producing and distributing Certified, Registered, and Foundation Seed. A logical series of steps would be:

- Strengthen NAPIO's technical capacity and expand the budget for seed potato inspection

- Simplify seed potato marketing procedures, expanding the role of market prices in decision-making

- Establish a Seed Potato Producers Association (SPPA)

- Eliminate the fixed prices and quotas for Registered and Certified Seed and allow private farmers selected by the SPPA to purchase Foundation and Registered seed at prices that reflect true market values

- Transfer responsibility for production of Foundation Seed to the private sector

The first four steps could be taken virtually immediately and simultaneously. It may be prudent to delay the final step for one or two years after the initial reorganization of the Seed Program begins. However, it may be difficult to finance step one (which requires additional expenditures) until steps four and five (which reduce subsidies) are implemented. Hence, it may be most practical to implement all five steps simultaneously.

R&D Priorities

Korea's potato program has succeeded in increasing the country's potato yields by reducing virus levels in planting material. Nevertheless, average potato consumption remains low -- around 10 kg per head per year. There appear to be several reasons for this. Farmers still find that quality seed is scarce and costly. Given Korea's limited farmland area and the limited financial and human resources of the government agencies involved, it seems clear that a move toward greater private sector involvement in seed production could help alleviate this problem.

There is also a clear need is for greater genetic diversity. Korean farmers, consumers, and processors could make good use of new varieties adapted to the country's diverse ecological environments and to new uses of potatoes (particularly the production of chips and frozen french fries). Stepping up breeding and varietal selection would require more human resources, vehicles and funds for regional trials. At present only two senior researchers and five junior researchers are employed by the AES, HES and the Namhae sub-station to carry out all the tissue culture work and potato breeding. Vehicles, travel budget and time are so limited that researchers usually visit the few regional trials conducted by provincial RDA officers only once each year.

A third priority is post-harvest R&D. At present no storage work -- either for seed or table potatoes -- is being conducted by the program. Seed is seldom available during the winter months when snow blocks shipping from the alpine areas to the lowlands. This makes it difficult for farmers in the southern part of Korea to plant in late winter and early spring, when they would like to do so. Improved seed storage methods could help farmers plant off season and supply urban markets when supplies are scarce and prices are high. Improved methods for storing consumer potatoes could also allow farmers hold their crop off the market at the end of the main spring crop when prices are at their lowest.

One of the most difficult problems is expansion of potato production in the fall season, which is very short (bounded by hot, rainy weather at the beginning and by cold weather at the end of the season). Use of early varieties and true potato seed (TPS) offer potential solutions. Planting TPS may help farmers avoid the problem of rotting seed tubers. Preliminary results are promising, but more on-farm testing is needed.

In conclusion, now that the basic problems of clean seed production have been solved, the National Program needs to turn its attention to providing a broader range of varieties suitable for different agro-ecological zones, cropping systems, and processing. More attention also needs to be paid to the post-harvest sector, both to facilitate processing and to even the flow of fresh potatoes to the country's rapidly growing urban markets. More on-farm research is needed to identify farmers' and consumers' requirements and to test potential new technologies, like TPS, under representative farming conditions.

The resources needed for these tasks could be made available if some of the current seed production activities were transferred to the private sector.

Statistical Annex

The statistical annex contains background data on Korean agriculture, potato production and use and seed production and distribution. The figures, compiled from a number of sources, are presented in 21 tables grouped under four headings.

Annex 1. Potato Production

Annex 2. Seed Certification

Annex 3. Virus Levels

Annex 4. **Prices**

Annex 1. Potato Production

Table A 1.1. Harvested area, yield, production and consumption of potatoes in Korea 1953-86

Year	Area (000 ha)	Yield (t/ha)	Prodn (000 t)	Population (million)	Prodn per capita (kg)
1953	45	8.5	385		
1954	44	5.3	234		
1955	49	7.4	354	21.4	17
1956	48	7.5	363	22.0	16
1957	58	8.1	465	22.7	21
1958	49	8.7	423	23.3	18
1959	47	8.2	385	24.0	16
1960	47	8.9	421	24.7	17
1961	48	9.7	463	25.7	18
1962	49	8.5	412	26.4	16
1963	46	8.6	391	27.1	14
1964	47	12.2	571	27.8	21
1965	60	9.6	581	28.5	20
1966	60	11.4	688	29.2	24
1967	58	9.7	566	29.8	19
1968	60	10.3	617	30.5	20
1969	56	10.7	599	31.2	19
1970	54	11.3	605	31.9	19
1971	52	11.3	589	32.6	18
1972	43	10.6	459	33.2	14
1973	42	11.3	470	33.9	14
1974	43	10.9	469	34.6	14
1975	52	12.7	660	35.3	19
1976	49	11.7	569	35.9	16
1977	50	11.2	558	36.5	15
1978	39	7.8	304	37.0	8
1979	34	10.6	356	37.6	9
1980	37	11.9	446	38.1	12
1981	41	13.5	554	38.7	14
1982	36	15.0	539	39.3	14
1983	30	15.5	469	40.0	12
1984	26	16.8	436	40.6	11
1985	31	18.5	575	41.3	14
1986	28	20.4	577	41.9	14

Source: FAO. Basic Data Unit (unpublished) and United Nations <u>Demographic Yearbook 1966</u> (Geneva, 1967).

Table A 1.2. **Harvested area, production and yield of potatoes in three main cropping seasons 1982-86**

	Spring crop	Summer crop	Fall crop	Total
Area (ha)				
1982	29,528	3,956	2,538	36,022
1983	23,737	4,722	1,772	30,231
1984	19,758	4,662	1,507	25,927
1985	22,777	6,519	1,808	31,104
1986	20,646 a/	5,596	1,492	27,734
Production (t)				
1982	396,144	109,742	32,631	538,517
1983	341,444	105,257	22,246	468,947
1984	295,198	119,956	20,472	435,626
1985	365,413	186,076	23,640	575,129
1986	384,016	161,612	20,052	565,680
Yield (t/ha)				
1982	13.4	27.7	12.9	14.9
1983	14.4	22.3	12.6	15.5
1984	14.9	25.7	13.6	16.8
1985	16.0	28.5	13.1	18.5
1986	18.6	28.9	13.4	20.4

Source: MAF. Official estimates. a/ Includes 802 ha in winter season.

Table A 1.3. Potato production, area and yield by province 1970–85

	1970	1975	1980	1985
Production (t)				
Kyonggi	69,127	79,023	23,156	19,473
Kangweon	177,318	179,563	128,792	291,511
Chungbuk	65,038	54,233	28,208	20,633
Chungnam	31,756	46,027	30,576	16,294
Chonbuk	62,902	35,325	36,792	26,465
Chonnam	34,825	46,188	45,629	60,045
Kyongbuk	105,510	140,657	54,845	59,869
Kyongnam	56,033	79,112	80,373	63,316
Cheju	2,644	14,671	17,732	17,523
Total	605,151	674,798	446,104	575,129
Harvested area (ha)				
Kyonggi	5,264	5,602	2,346	1,596
Kangweon	14,658	13,645	10,088	12,103
Chungbuk	5,546	4,512	2,720	1,514
Chungnam	3,270	3,842	2,896	1,313
Chonbuk	5,544	2,939	2,821	1,750
Chonnam	3,365	3,354	3,272	3,988
Kyongbuk	10,943	11,702	6,249	3,613
Kyongnam	5,247	6,301	5,895	4,044
Cheju	146	795	1,105	1,187
Total	53,983	52,692	37,392	31,104
Yield (t/ha)				
Kyonggi	13.1	14.1	9.9	12.2
Kangweon	12.1	13.2	12.8	24.1
Chungbuk	11.7	12.0	10.4	13.6
Chungnam	9.7	12.0	10.6	12.4
Chonbuk	11.3	12.0	13.0	15.1
Chonnam	10.3	13.8	13.9	15.1
Kyongbuk	9.6	12.0	8.8	16.6
Kyongnam	10.7	12.6	13.6	15.7
Cheju	18.1	18.5	16.0	14.8
Weighted average	11.2	12.8	11.9	18.5

Source: MAF. Statistical Yearbook of Agriculture, Forestry and Fisheries (Seoul, various years).

Annex 2. Seed Certification

Table A 2.1. Spring and summer crops: Basic, Elite, Foundation, Registered and Certified Seed produced 1961-85

Year	Basic Seed area (ha)	Basic Seed prodn (t)	Elite I Seed area (ha)	Elite I Seed prodn (t)	Elite II Seed area (ha)	Elite II Seed prodn (t)	Foundation Seed area (ha)	Foundation Seed prodn (t)	Registered Seed area (ha)	Registered Seed prodn (t)	Certified Seed area (ha)	Certified Seed prodn (t)
1961							9	82			50	500
1962			2.0	8			9	82			50	500
1963			2.0	12			9	38			86	860
1964			3.0	18			9	73			77	617
1965			2.3	17			13	63			68	680
1966			3.6	13			13	130			33	331
1967			3.6	22			10	122			60	600
1968			3.6	22			13	144			83	834
1969			1.3	9	6.7	44	13	147			89	894
1970			1.3	8	6.7	43	27	270	133	1,036	112	1,120
1971			1.7	9	7.0	43	27	233	133	941	122	1,119
1972			1.5	8	5.5	33	25	240	133	1,330	198	1,379
1973			1.9	11	9.4	39	29	292	163	1,348	371	2,964
1974			2.2	11	8.8	46	35	216	200	1,400	471	3,274
1975			2.2	11	8.9	45	34	270	225	1,440	502	2,961
1976			1.7	10	7.6	38	28	251	188	1,501	750	6,139
1977			1.9	10	8.3	42	31	297	140	1,126	774	4,965
1978			1.8	13	7.5	38	31	183	150	1,012	622	3,169
1979			3.0	10	9.3	47	31	133	110	536	595	a/
1980			5.5	25			17	151	80	915	127	1,939
1981	0.2	1.5	2.5	23			9	147	80	849	330	3,340
1982	0.2	1.7	2.5	27			12	176	80	1,140	465	4,665
1983	0.2	3.1	2.5	24			13	150	80	1,504	333	4,367
1984	0.2	1.8	1.7	15			11	121	55	1,140	346	4,770
1985	0.3	2.0	1.4	14			10	114	36	793	304	4,564

Source: AES, PSF, and OSPD records. a/ All Certified Seed fields were rejected in 1979 due to heavy virus infection. Blank spaces indicate that no seed of the respective class was produced that year. Basic, Elite, and Foundation Seed is produced by AES; Registered Seed is produced by PSF. Certified Seed is produced by contract seed growers, under the supervision of OSPD.

Table A 2.2. Fall and winter crops: Basic, Elite, Foundation, Registered and Certified Seed produced 1966-86

Year	Basic Seed area (m^2)	Basic Seed prodn (kg)	Elite I Seed area (ha)	Elite I Seed prodn (t)	Elite II Seed area (ha)	Elite II Seed prodn (t)	Foundation Seed area (ha)	Foundation Seed prodn (t)	Registered Seed area (ha)	Registered Seed prodn (t)	Certified Seed Fall Crop area (ha)	Certified Seed Fall Crop prodn (t)	Certified Seed Winter Crop area (ha)	Certified Seed Winter Crop prodn (t)
1966							3.4	26						
1967							3.4	26						
1968			1.1	4.8			3.4	26						
1969			0.1	0.9	0.6	4.2	3.4	27						
1970			0.1	0.9	0.6	3.1	1.7	14						
1971			0.1	0.9	0.6	3.4	1.7	17						
1972			0.1	0.9	0.5	3.0	3.4	30						
1973			0.2	1.0	0.8	4.0	3.4	30						
1974			0.2	1.0	0.8	4.0	3.4	30						
1975			0.2	1.0	0.8	4.0	3.4	28						
1976			0.2	1.0	0.8	4.4	3.4	27						
1977			0.2	1.2	0.8	4.5	3.4	27						
1978			0.2	1.0	0.8	4.5	4.0	25						
1979 a/			1.0	6.3			3.4	27	16	60				
1980			1.3	9.8			4.0	27	16	43	37	335		
1981	300	420	1.3	6.0			3.4	27	16	100	22	170		
1982	300	420	1.3	7.0			3.6	33	21	197	17	245		
1983	300	420	1.3	9.0			3.2	33	10	109	11	173		131
1984	300	480	1.3	7.0			2.9	29	13	121	12	116	14	200
1985	300	480	1.3	5.4			3.0	36	15	165	17	250	40	650
1986	300	480	1.3	5.4			3.0	36	20	260	16	250	50	800

Source: AES, HES, and OSFD records. a/ Prior to 1979, AES produced Elite Seed, HES produced Foundation and Registered Seed, and KHCA produced Certified Seed. After 1979, HES became responsible for producing Basic, Elite, and Foundation Seed, and OSFD began producing Registered and Certified Seed, through contracts arrangements with private farmers. Blank spaces indicate that no seed of the respective class was produced that year or that records are not available due to the change of responsible organization.

Table A 2.3. Foundation Seed for spring and summer crops: production and use 1979-85

	Area (ha)	Seed planted	Seed harvested	Recipient of harvested seed PSF	OSPD	KHCA	Other a/
		(........................		t	....		........)
1979	31.3	37.5	198	0	133	65	0
1980	16.2	19.8	190	104	0	77	9
1981	8.5	10.2	172	113	0	16	43
1982	11.7	14.0	251	132	44	75	0
1983	12.5	19.0	272	126	24	104	18
1984	11.0	17.0	226	120	0	105	1
1985	9.5	12.0	188	148	0	33	7

Source: AES records. a/ Primarily used for research.

Table A 2.4. Registered Seed for spring and summer crops: production and use 1983-85

	1983	1984	1985
Total production (t)	1,504	1,141	1,553
Registered Seed delivered to OSPD (t)	241	398	515
Certified Seed sold to farmers (t)	531	248	660
Other uses and losses (t)	732	495	378
Total area planted (ha)	80	55	80
Total yield (t/ha)	18.8	20.7	19.4
Yield of Registered Seed (t/ha)	3.0	7.2	6.4
Yield of Registered and Certified Seed (t/ha)	9.7	11.7	14.7

Source: PSF records.

Table A 2.5. Certified Seed: production statistics of KHCA 1961-85

	Number of seed growers	Average area inspected (ha)	Area which passed inspection: % area inspected	Area which passed inspection: ha	Certified Seed produced (t): total	Certified Seed produced (t): per ha	Price received for Certified Seed a/ (kg)
1961			100	50	500	10.0	
1962			100	50	500	10.0	
1963			100	86	860	10.0	
1964			100	77	617	8.0	
1965			100	68	680	10.0	
1966			100	33	331	10.0	
1967			100	60	600	10.0	
1968			100	83	834	10.0	
1969			100	89	894	10.0	
1970	166	0.7	100	112	1,120	10.0	22
1971	193	0.6	100	122	1,119	9.2	30
1972	214	1.4	64	198	1,379	7.0	32
1973	302	1.4	90	371	2,964	8.0	42
1974	382	1.3	95	471	3,274	7.0	57
1975	342	1.6	92	502	2,961	5.9	66
1976	288	1.7	95	478	4,100	8.6	76
1977	361	1.6	88	513	3,300	6.4	93
1978	336	1.3	56	239	2,062	8.6	234
1979	333		0	0	0	0	
1980	40	2.1	98	82	812	9.9	330
1981	147	1.4	100	210	2,108	10.0	340
1982	149	1.9	99	277	3,626	13.1	345
1983			100	222	2,913	13.1	345
1984			100	231	2,310	10.0	345
1985			100	248	2,483	10.0	345

Source: KHCA records. a/ All prices are for Irish Cobbler variety. The price of superior was ₩330/kg in 1984 and ₩340/kg in 1985. **Blank spaces** signify that no data are available.

Table A 2.6. Certified Seed: production under the auspices of OSPD-Daekwalryung Branch 1976-85

	Area (ha)	Seed produced per ha	Seed produced total	Seed produced by variety a/ Irish cobbler	Superior	Dejima
		(.................... t	....	....	....	.....................)
1976	750	8.3	6,200	6,200	0	0
1977	774	6.5	5,019	5,019	0	0
1978	621	5.5	3,427	3,427	0	0
1979	595	0	0	0	0	0
1980	126	9.8	1,230	1,230	0	0
1981	333	10.0	3,315	3,315	0	0
1982	465	12.4	5,750	4,408	1,346	0
1983	333	13.0	4,334	2,873	1,312	149
1984	346	13.2	4,583	2,158	2,215	210
1985	304	18.0	5,480	662	4,157	661

Source: OSPD-Daekwalryung Branch records. a/ Irish Cobbler and Superior are produced for the spring and summer crops. Dejima is produced for the winter crop.

Table A 2.7. **Certified Seed Potatoes: national production estimates 1965-84**

	Number of fields inspected	Average field size (ha)	Area which passed inspection		Certified Seed produced a/	
			% area inspected	total (ha)	total (t)	per ha (t)
1965	5,718	0.16	91	827	2,688	3.2
1966	4,217	0.22	82	761	2,605	3.4
1967	3,556	0.22	86	683	3,104	4.5
1968	5,116	0.20	94	987	7,243	7.3
1969	4,405	0.27	89	1,092	5,866	5.4
1970	3,960	0.28	94	1,057	7,437	7.0
1971	4,426	0.25	76	849	6,005	7.1
1972	3,893	0.32	64	789	6,161	7.8
1973	6,790	0.25	80	1,361	9,798	7.2
1974	4,694	0.34	83	1,336	9,288	7.0
1975	3,630	0.41	84	1,247	6,111	4.9
1976	1,697	0.44	95	750	6,191	8.2
1977	1,285	0.60	90	700	5,019	7.2
1978	1,027	0.50	86	448	3,427	7.6
1979	3,868	0.20	11	88	651	7.4
1980	432	0.49	95	202	1,599	7.9
1981	876	0.52	98	448	3,613	8.1
1982	1,208	0.51	96	592	6,228	10.5
1983	821	0.53	100	434	4,978	11.5
1984	830	0.56	100	462	6,013	13.0

Source: MAF. Statistical Yearbook of Agriculture, Forest & Fisheries (Seoul, various years). a/ Amount of seed which passed inspection. Seed potato inspection was first reported in the Statistical Yearbook in 1965.

Table A 2.8. Certified Seed Potatoes sold in each Province 1983-85 (t)

Province a/	1983	1984	1985
Kyonggi	460	500	605
Kangweon	1,313	1,462	1,717
Chungbuk	224	322	359
Chungnam	194	203	231
Chonbuk	207	258	296
Chonnam	168	316	328
Kyongbuk	750	748	1,025
Kyongnam	718	735	791
Cheju	131	205	646
Not specified	202	21	0
Total	4,367	4,770	5,998

Source: OSPD-Daekwalryung Branch records. a/ All seed produced in the Alpine area is for the spring and summer crops except that sold in Cheju, which is for the winter crop.

Table A 2.9. Registered and Certified Seed prices 1976-85 (₩/kg)

	Price paid by contract growers for Registered Seed a/	Price of Certified Seed			
		purchase price b/		selling price c/	
		Irish cobbler	Superior Dejima	in the spring	in the fall
1976		76		78	
1977		93		111	
1978		234		280	
1979 d/	--	--	--	--	--
1980		330		380	347
1981	214	340		400	374
1982	214	345	345	410	390
1983	214	345	345	410	390
1984	214	345	330	410	380
1985	214	345	340	410	390

Source: OSPD-Daekwalryung Branch records. a/ This is the price at which the PSF delivers Registered Seed to OSPD. b/ This is the price that OSPD pays contract growers for Certified Seed. c/ OSPD sells Certified Seed at a uniform price throughout Korea. d/ Due to high virus levels in seed fields, no seed was certified in 1979. Blank spaces signify that no data are available.

Annex 3. Virus Levels

Table A 3.1. Plants with visual symptoms of virus diseases in Foundation Seed fields of Irish Cobbler variety 1979-85 (%)

	Plants eliminated before inspection a/	Virus observed at inspection	Total virus
1979	23.4	4.6	28.0
1980	7.4	1.6	9.0
1981	2.4	1.1	3.5
1982	1.9	0.2	2.1
1983	0.1	0.1	0.2
1984	0.1	0.1	0.2
1985	0.1	0.1	0.2

Source: AES records. a/ Plants with visual symptoms of virus diseases are eliminated from the field, or "rogued out" before the field is officially inspected by NAPIO.

Table A 3.2. Plants and tubers with visual symptoms of virus diseases in Registered Seed fields 1980-85

	Plants in field			Tubers in winter test b/	
	plants eliminated a/	virus at inspection	total virus	Irish Cobbler	Superior
1980	12.9	2.3	15.2	5.3	
1981	5.0	0.6	5.6	n.d.	
1982	9.1	0.1	9.2	7.8	0.8
1983	3.7	0.3	4.0	15.6 c/	0.2
1984	5.6	0.3	5.9	2.0	0.5
1985	1.0	0.2	1.2	0.0	0.0

Source: PSF records. a/ See footnote a/ Table A 3.1. b/ The winter test is conducted at HES, Suweon. c/ Imported seed.

Table A 3.3. Total virus diseases observed in Certified Seed fields by variety (% plants)

	Irish Cobbler a/	Superior b/	Dejima c/
1981	10.6		
1982	13.1	11.6	
1983	7.3	4.1	15.8
1984	17.2	5.1	6.6
1985	4.1	5.9	7.7

Source: OSPD - Daekwalryung Branch records. a/ The virus level was high in 1984 because many growers used Cert_fied Seed, rather than Registered Seed, as planting material. The first locally produced tissue culture lines of Irish Cobbler reached Certified Seed growers in 1985. b/ The first locally produced tissue culture lines of Superior reached Cercified Seed growers in 1983. c/ Basic and Foundation Seed of Dejima, which are certified for winter-season growers in Cheju Island, are produced by HES in Suweon and Namhae.

Table A 3.4. Plants with visual symptoms of virus diseases in Foundation, Registered and Certified Seed fields (%)

	Foundation Seed			Registered Seed			Certified Seed		
	plants eliminated a/	virus at inspection	Total virus	plants eliminated a/	virus at inspection	Total virus	plants eliminated a/	virus at inspection	Total virus
Irish cobbler variety									
1978	14.0	1.1	15.1	26.9	3.5	30.4	15.0	20.0	35.0
1979	21.4	0.6	22.0	61.0	3.0	64.0	b/	b/	
1980	6.4	0.5	6.9	9.0	2.3	11.3	8.5	3.0	11.5
1981	1.9	0.3	2.2	5.5	0.6	6.1	3.1	1.3	4.4
1982	1.9	0.2	2.1	9.1	0.1	9.2	9.5	2.7	12.2
1983	0.1	0.2	0.3	6.2	1.1	7.3	5.2	1.4	6.6
1984	0.1	0.1	0.2	8.2	0.3	8.5	16.8 c/	0.4	17.2
1985	0.2	0.2	0.4	1.9	0.2	2.1	3.7	0.4	4.1
Superior variety									
1984	0.1	0.1	0.2	2.8	0.3	3.1	4.9	0.2	5.1
1985	0.1	0.2	0.3	0.7	0.2	0.9	5.4	0.5	5.9
Dejima variety									
1984							6.3	0.4	6.7
1985							7.1	0.6	7.7

Source: NAPIO records. a/ See footnote a/ Table A 3.1. b/ All fields were rejected due to heavy virus infection. c/ Virus infection was heavy in 1984, because many farmers multiplied Certified Seed a second time. **Blank spaces** signify that no data are available.

Table A 3.5. **Virus symptoms observed in lowland potato fields in spring crops 1979-83**

		Severe mosaic a/	Mild mosaic a/	Leaf roll	Total virus	Number of observations b/
1979		27	14	25	66	37
1980		14	14	16	44	36
1981		10	11	21	42	35
1982	average	3	6	9	18	25
	own seed	4	10	29	44	4
	purchased	2	5	5	12	21
1983	average	3	8	15	26	10
	own seed	4	12	34	49	4
	purchased	2	5	3	10	6

Source: Derived from AES Annual Research Reports. a/ The term mosaic indicates the presence of Potato Viruses X or Y. b/ No rigorous sampling procedure was used to select fields for observation. Hence, while these figures reflect the general decline since 1979, they should not be interpreted to be precise estimates of virus levels in farmers' fields.

Table A 3.6. **Percent total virus infection and relative yield of Alpine and lowland seed planted at Alpine Experiment Station 1966**

Seed source	Total virus (%)	Relative yield (%)
Alpine area	23	100
Lowlands	95	34

Source: Choi Chung Il and Kang, Eung Hee. "Some experiments on potato virus." Alpine Experiment Station Annual Research Report (Taekwanryong, 1966).

Annex 4. Prices

Table A 4.1. Annual average price indexes, exchange rates and prices of seed and consumer potatoes 1961-86

	Wholesale price index		Index all prices received by farmers	Exchange rate	Farm-gate prices							Value of potato production	
					current W/3.75 kg		1985 W/3.75 kg		current US$/kg		Relative seed		
	total	food	(1985=100)	(W/US$)	table potatoes	seed potatoes	table potatoes	seed potatoes	table potatoes	seed potatoes	price a/	current W * 10⁶	current US$*10⁶
1961	6.5	3.6		127.5	30				0.04			6,419	50.35
1962	7.1	3.9		130.0	27				0.06			5,718	43.98
1963	8.6	5.5	4.3	130.0	44		1,029		0.09			5,421	41.70
1964	12.0	7.6	5.4	213.8	57		1,063		0.07			7,912	37.01
1965	13.0	7.5	5.6	266.3	51		914		0.05			8,051	30.23
1966	14.0	8.0	5.9	271.3	52		875		0.05			9,545	35.18
1967	15.0	6.8	6.8	270.5	61	86	896	1,263	0.06	0.08	141	9,209	34.04
1968	16.0	9.7	8.0	276.6	58	108	728	1,255	0.06	0.10	186	9,543	34.50
1969	17.0	11.0	9.4	288.2	54	99	573	1,051	0.05	0.09	183	8,630	29.94
1970	19.0	13.0	10.9	310.6	60	142	552	1,306	0.05	0.12	237	10,005	32.21
1971	20.0	16.0	13.0	348.2	78	172	598	1,319	0.06	0.13	221	12,724	36.54
1972	23.0	20.0	15.9	392.9	108	176	677	1,104	0.07	0.12	163	13,206	33.61
1973	25.0	20.0	17.4	398.3	142	199	817	1,144	0.10	0.13	140	17,804	44.70
1974	35.0	26.0	23.2	405.4	211	313	910	1,350	0.14	0.21	148	26,399	65.93
1975	40.0	37.0	28.3	484.0	195	307	690	1,086	0.11	0.17	157	34,338	70.95
1976	50.0	47.0	35.5	484.0	260	324	732	912	0.14	0.18	125	39,444	81.50
1977	54.0	55.0	41.3	484.0	345	386	835	935	0.19	0.21	112	51,332	106.06
1978	61.0	71.0	53.6	484.0	612	569	1,141	1,061	0.34	0.31	93	49,625	102.53
1979	72.0	80.0	59.4	484.0	726	776	1,222	1,306	0.40	0.43	107	68,853	142.26
1980	100.0	100.0	72.5	607.4	667	1,006	930	1,388	0.29	0.44	151	78,752	129.65
1981	130.0	128.0	92.8	681.0	689	1,236	743	1,333	0.27	0.48	179	99,181	145.64
1982	126.0	128.0	99.3	731.1	539	1,221	543	1,230	0.30	0.45	227	77,403	105.87
1983	126.0	132.0	101.4	775.8	669	1,268	659	1,250	0.23	0.44	190	83,660	107.84
1984	127.0	129.0	100.7	806.0	656	1,277	651	1,268	0.22	0.42	195	76,205	94.55
1985			100.0	870.0	876	1,474	876	1,474			168		
					782	1,513							

Source: MAF. Statistical Yearbook of Agriculture, Forestry and Fisheries (Seoul, various years) and International Monetary Fund. International Financial Statistics. 1985. a/ (Seed potato price/table potato price)*100.

Table A 4.2. Annual average farm-gate prices of selected agricultural commodities 1961-84 (current W/kg)

	Potato	Sweet potato	Rice: native varieties	Rice: new varieties	Naked barley	Corn	Tomato	Chinese cabbage	Radish	Cabbage
1961	5	4	20		13	10	8	5	3	7
1962	7	5	22		15	11	11	4	4	8
1963	12	5	34		25	17	22	7	6	12
1964	15	11	43		32	28	30	12	8	13
1965	14	8	40		22	19	30	9	7	18
1966	14	9	42		20	24	18	9	7	13
1967	16	10	47		25	25	20	14	11	30
1968	15	11	55		28	27	23	12	11	18
1969	14	13	68		34	26	30	13	13	14
1970	16	15	76		39	28	26	25	21	22
1971	21	19	96		54	33	23	20	18	34
1972	29	23	122		71	41	40	17	14	22
1973	38	29	128		73	49	41	22	18	29
1974	56	45	184		92	70	61	28	29	57
1975	52	51	233		129	84	72	45	40	46
1976	69	62	281		131	93	95	38	37	65
1977	92	82	311		196	105	111	76	68	81
1978	163	97	364		225	119	179	88	62	135
1979	194	115	472		252	130	258	79	68	107
1980	178	127	611	501	316	195	235	77	72	104
1981	184	166	695	619	367	214	221	90	94	139
1982	144	163	718	646	417	210	160	72	61	72
1983	178	140	735	638	428	234	239	92	70	117
1984	175	157	754	655	442	276	215	70	67	139

Source: MAF. Statistical Yearbook of Agriculture, Forestry and Fisheries (Seoul, various years) and International Monetary Fund. International Financial Statistics. 1985.

Table A 4.3. Monthly average deflated farm-gate potato prices 1972-86 (W/3.75 kg) a/

	1972	1973	1974	1975	1976	1977	1978	1979	1980	1981	1982	1983	1984	1985	Average prices 1972-76	1977-81	1982-85
January	656	741	783	782	731	780	785	1,268	1,111	828	618	667	732	937	739	955	758
February	663	765	987	814	667	817	839	1,313	1,247	1,049	606	723	707	937	779	1051	766
March	663	824	1,106	854	653	868	831	1,319	1,189	1,065	733	835	830	937	819	1054	834
April	706	871	1,096	871	716	908	933	1,426	1,200	923	735	937	860	1,257	850	1080	947
May	769	865	1,148	868	781	1,051	861	1,566	1,229	1,010	585	738	758	1,151	896	1145	808
June	719	835	952	668	761	838	1,220	1,296	938	611	358	653	547	852	787	909	602
July	606	735	730	518	683	712	1,174	1,173	728	606	343	636	535	673	655	879	547
August	606	829	722	550	728	783	1,159	1,100	764	680	442	486	577	749	687	903	564
September	675	915	830	607	756	805	1,224	1,117	810	745	469	537	740	886	757	960	658
October	725	941	865	718	797	829	1,248	1,127	947	637	524	660	632	950	809	958	692
November	775	971	909	729	772	898	1,331	1,171	893	673	591	642	732	927	835	991	723
December	781	1,012	948	764	825	946	1,385	1,222	953	745	657	673	834	928	866	1010	785
IPR (1985=100) b/	16	17	23	29	36	41	51	59	72	93	99	101	101	100			
Average	666	859	923	724	740	864	1,077	1,258	1,001	798	579	682	711	932	789	1010	724
STD	58	85	138	113	53	93	216	134	181	165	135	115	113	148	67	75	113
CV	8	10	15	16	7	11	20	11	18	21	24	17	16	16	9	7	16
Maximum	781	1012	1,148	871	825	1,051	1,385	1,566	1,247	1,065	735	937	834	1,257	896	1145	947
Minimum	606	735	722	518	653	712	785	1,100	728	606	343	486	535	673	655	879	547

Source: National Agricultural Cooperative Federation. Monthly Review (various years) and Annex Table A 4.1.

a/ Current farm-gate price for grade A potatoes deflated by the index of all prices received by farmers (1985=100). b/ IPR = index of all prices received by farmers.

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